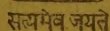


EXT M

EXT M

COMMONWEALTH INST.  
ENTOMOLOGICAL LIBRARY  
22 NOV 1950  
IND  
AS. 60<sup>B</sup>  
ACRIGI

**The Indian Council of Agricultural Research**



Price per part  
Rs. 4 or 6s. 6d.

ICAR. 5. XIX. I.  
600.

## CONTENTS

VOL. XIX, PART I

( March, 1949 )

**The Publications Committee of the Indian Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal**

PAGE

### Original articles

- RAINFALL OF INDIA : A BRIEF REVIEW *L. A. Ramdas* 1  
(WITH SEVEN TEXT FIGURES)
- PRELIMINARY STUDIES ON THE ESTABLISHMENT OF COLOUR STANDARDS IN RELATION TO SOIL CONSTANTS (WITH PLATE 1 AND FOUR TEXT FIGURES) *A. G. Asghar, C. L. Dhawan and K. D. Bhola* 21
- STUDIES ON BUNDELKHAND SOILS OF UNITED PROVINCES, III. PEDOCHEMICAL CHARACTERISTICS OF THE BLACK SOILS OF THE PLAINS *R. R. Agarwal and P. Mukerji* 31
- THE RELATIVE IMPORTANCE OF ORGANIC MANURES AND INORGANIC FERTILIZERS IN TROPICAL SOILS *S. Das* 41
- DEVELOPMENT OF COTTON SEED AND LINT DURING THE SECOND PHASE OF BOLL MATURATION (WITH EIGHT TEXT FIGURES) *S. M. Nawaz* 61
- THE SURVEY OF *Pollu* AND ROOT DISEASES OF PEPPER (WITH TWO TEXT FIGURES) *K. Krishna Menon* 89
- STUDIES IN THE CLARIFICATION OF SUGARCANE JUICE IN *Gur* MANUFACTURE *K. L. Khanna and A. S. Chacravarti* 137
- INVESTIGATION ON THE ALKALINITY AND SALTISHNESS IN *Gur* MADE FROM COIMBATORE SUGARCANE VARIETIES *P. G. Krishna* 163

### REVIEWS

- CHEMICAL COMPOSITION OF PLANTS AS AN INDEX OF THEIR NUTRITIONAL STATUS 181
- FARM SCIENCE AND CROP PRODUCTION IN INDIA 182

## RAINFALL OF INDIA: A BRIEF REVIEW \*†

By L. A. RAMDAS, Director of Agricultural Meteorology, Meteorological Office, Poona

A DETAILED discussion of Indian rainfall would fill volumes. In a short article like the present all one can attempt is to take a bird's-eye view of the subject. A history of Indian rainfall is really a history of the well-known south-west monsoon. We have reliable records for about 60 years. As judged by these records, what is the dependability of rainfall in different parts of this vast sub-continent, and what are the chances of success of agriculture in different parts of the country? How often in a century is the monsoon rainfall so conspicuously in excess (flood) or in defect (drought) as to cause widespread havoc and failure of crops? Which are the regions in India with minimum of weather-risk? Do such risks occur at random or is there any regularity or law governing the time and place of their occurrence? What are the large-scale and long-term measures which the State can undertake in order to reduce weather-risks? In what parts of India will such developments be practicable? These are some of the questions which deserve consideration. In what follows, resort will be had to self-explanatory diagrams and tables so as to secure brevity.

### PHYSICAL AND CLIMATIC FEATURES

Figs. 1 and 2 show the distribution of the mountain and river-systems and of the normal annual rainfall of India. The areas of very heavy rainfall are to the windward side of the Western Ghats, the hills of Assam, and the great Himalayan barrier. These are the watersheds from which originate the major river-systems of the country. Elsewhere, in the plateau of the Deccan, the Gangetic plains of North India, and the plains of the Carnatic, the effects of orography are less pronounced or are completely absent and the rainfall is only moderate. In the north-west, the Punjab, N.W. Frontier Province, Sind, Baluchistan, and the desert of Rajputana constitute the driest area of the country.

Table I gives the normal rainfall in different seasons of the year and during the year as a whole in the 30 subdivisions into which India may be divided (see Fig. 3). The four seasons are: winter, December to February; summer or pre-monsoon, March to May; monsoon, June to September; post-monsoon, October to November. In columns (2) to (5) the figures within brackets are the seasonal amounts expressed as percentages of the annual rainfall.

A study of these figures reveals at once that India is truly the land of the monsoons. With the exception of Kashmir, the N.W. Frontier Province, and Baluchistan in the north and SE. Madras in the south, *a very large percentage of the annual rainfall over the country occurs during the south-west monsoon (June to September)*. In the extreme north a good proportion of the annual rainfall is contributed by winter precipitation, whilst in SE. Madras nearly half the annual rainfall occurs during the post- or retreating monsoon period (i.e., after September).

\* Reproduced with permission from the *Empire Journal of Experimental Agriculture* XIV (54), April 1946.

† The article deals with undivided India.

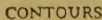


FIG. 1. Relief map of India

Besides the setting in of the monsoon early in June, its extension into India during June and July, and finally its retreat southwards in September and October, we have also to consider the other major phenomena like cyclonic storms and depressions.

TABLE I

*Normal seasonal rainfall in the 30 rainfall subdivisions of India in inches*

Subdivision (1)	Winter December to February (2)	Summer or Pre-monsoon March to May (3)	Monsoon June to September (4)	Post-monsoon October to November (5)	Year (6)
1. Assam	2.38 (2.4) per cent	25.06 (25.7) per cent	64.26 (65.8) per cent	5.96 (6.1) per cent	97.66
2. Bengal	1.53 (2.0)	12.42 (16.5)	56.01 (74.5)	5.17 (6.9)	75.13
3. Orissa	1.82 (3.2)	5.62 (9.9)	44.49 (78.2)	4.98 (8.8)	56.91
4. Chota Nagpur	2.57 (5.0)	3.64 (7.1)	42.71 (83.4)	2.26 (4.4)	51.18
5. Bihar	1.41 (2.9)	3.30 (6.8)	40.96 (85.0)	2.54 (5.3)	48.21
6. U. P. East	1.53 (3.9)	1.12 (2.9)	34.44 (88.0)	2.04 (5.2)	39.13
7. U. P. West	2.27 (6.0)	1.36 (3.6)	32.98 (87.8)	0.97 (2.6)	37.58
8. Punjab, E. & N.	2.76 (11.9)	1.89 (8.1)	18.23 (78.4)	0.37 (1.6)	23.25
9. Punjab, SW.	1.28 (13.7)	1.36 (14.5)	6.58 (70.4)	0.13 (1.4)	9.35
10. Kashmir	9.12 (22.1)	9.09 (22.0)	22.19 (53.7)	0.94 (2.3)	41.34
11. N. W. F. P.	3.36 (20.0)	4.18 (24.9)	8.65 (51.5)	0.62 (3.7)	16.81
12. Baluchistan	3.50 (45.6)	2.03 (26.4)	1.89 (24.6)	0.26 (3.4)	7.68
13. Sind	0.67 (10.4)	0.41 (6.4)	5.28 (82.4)	0.08 (1.2)	6.44
14. Rajputana, W.	0.62 (4.8)	0.56 (4.3)	11.74 (90.0)	0.12 (0.9)	13.04
15. Rajputana, E.	0.96 (3.8)	0.78 (3.1)	22.91 (90.9)	0.55 (2.2)	25.20
16. Gujerat	0.22 (0.7)	0.24 (0.7)	31.46 (96.2)	0.77 (2.4)	32.69
17. C. India, West	0.85 (2.5)	0.47 (1.4)	31.56 (93.8)	0.75 (2.2)	33.63
18. C. India, East	1.44 (3.7)	3.79 (2.0)	35.05 (90.9)	1.30 (3.4)	38.58
19. Berar	1.01 (3.1)	0.96 (3.0)	28.10 (87.4)	2.07 (6.4)	32.14
20. C. P. West	1.47 (3.2)	1.14 (2.5)	41.04 (90.4)	1.76 (3.9)	45.41
21. C. P. East	1.58 (3.0)	2.10 (4.0)	46.37 (89.1)	1.99 (3.8)	52.04

TABLE I—*contd.**Normal seasonal rainfall in the 30 rainfall subdivisions of India in inches—contd.*

Subdivision	Winter December to February	Summer or Pre-monsoon March to May	Monsoon June to September	Post-monsoon October to November	Year
(1)	(2)	(3)	(4)	(5)	(6)
22. Konkan	0.28 (0.3)	1.85 (1.7)	102.45 (93.7)	4.75 (4.3)	109.33
23. Bombay Deccan	0.51 (1.7)	2.13 (6.9)	24.41 (79.1)	3.82 (12.4)	30.87
24. Hyderabad, N.	0.67 (1.9)	1.53 (4.4)	29.51 (84.5)	3.20 (9.2)	34.91
25. Hyderabad, S.	0.57 (1.9)	2.10 (7.0)	23.38 (78.1)	3.88 (13.0)	29.93
26. Mysore	0.73 (2.0)	5.47 (15.2)	22.27 (61.8)	7.54 (20.9)	36.01
27. Malabar	2.73 (2.6)	12.61 (12.2)	71.47 (68.9)	16.93 (16.3)	103.74
28. Madras, SE.	4.76 (13.6)	4.53 (12.9)	12.01 (34.2)	13.80 (39.3)	35.10
29. Madras, Deccan	0.74 (3.0)	2.42 (9.9)	15.27 (62.3)	0.09 (24.8)	24.52
30. Madras, Coast N.	1.69 (4.2)	3.44 (8.9)	25.03 (62.3)	10.00 (24.9)	40.16

*Eastern depressions*

The fluctuations in the intensity of the monsoon itself are to a large extent associated with a series of depressions which mostly originate (or, when they are coming from farther east, strengthen) at the head of the Bay of Bengal and travel in a north-westerly direction across the country towards NW. India, causing heavy rainfall along their track. The frequency of such depressions is three or four per month during the monsoon months (June to September).

*Western depressions*

During the period November to May a series of western depressions enter India through Baluchistan and the NW. frontier and move eastwards across North India towards NE. India (Assam-Bengal). These depressions cause cloudy weather and light rains in the plains with snowfall in the Himalayas and are followed by cold waves. Their frequency is, on the average, two in November, four to five per month during December to April, and about two in May.

*(3) Cyclonic storms*

The more severe cyclonic storms usually form in the Bay of Bengal and in the Arabian Sea in the transition periods April to June and October to December. They enter inland and cause considerable precipitation and damage due to high winds and, occasionally, tidal waves, in the coastal tracts. The mode of occurrence of these storms and their favourite tracts have been discussed in the publications of the India Meteorological Department. On an average one or two severe cyclones may be expected in the pre-monsoon period and two or three in the post-monsoon period.

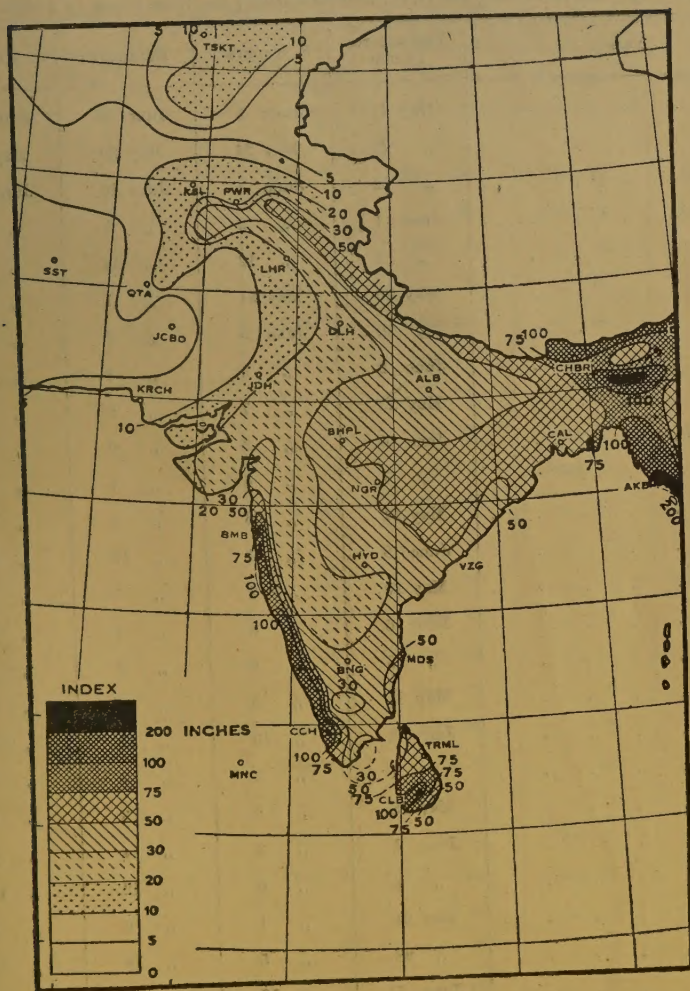


FIG. 2. Annual rainfall in India

TABLE II

*Date of establishment of the S.W. monsoon along the West Coast of India*

Year	Travancore-Cochin	S. Kanara	Ratanagiri	Kolaba
1891 . . . . .	May 27	June 3	June 19	June 21
1892 . . . . .	„ 22	May 24	May 29	May 31
1893 . . . . .	„ 22	June 4	June 10	June 10
1894 . . . . .	June 1	„ 2	„ 7	„ 7
1895 . . . . .	„ 8	„ 12	„ 14	„ 15
1896 . . . . .	May 30	May 31	„ 1	„ 1
1897 . . . . .	„ 30	June 5	„ 7	„ 7
1898 . . . . .	June 2	„ 3	„ 8	„ 8
1899 . . . . .	May 23	„ 7	„ 9	„ 10
1900 . . . . .	June 6	„ 8	„ 9	„ 9
1901 . . . . .	„ 1	„ 4	„ 7	„ 7
1902 . . . . .	May 31	„ 6	„ 7	„ 12
1903 . . . . .	June 8	„ 11	„ 12	„ 12
1904 . . . . .	May 29	„ 1	„ 7	„ 8
1905 . . . . .	June 6	„ 8	„ 9	„ 10
1906 . . . . .	„ 3	„ 6	„ 7	„ 8
1907 . . . . .	May 31	„ 5	„ 11	„ 11
1908 . . . . .	June 8	„ 10	„ 11	„ 11
1909 . . . . .	„ 1	„ 2	„ 3	„ 3
1910 . . . . .	May 28	„ 2	„ 3	„ 3
1911 . . . . .	June 1	„ 2	„ 4	„ 4
1912 . . . . .	„ 4	„ 6	„ 12	„ 12
1913 . . . . .	May 24	„ 1	„ 6	„ 7
1914 . . . . .	„ 28	„ 5	„ 13	„ 13
1915 . . . . .	June 3	„ 12	„ 17	„ 18
1916 . . . . .	May 26	May 27	May 31	„ 1
1917 . . . . .	„ 26	„ 29	June 4	„ 5

TABLE II—*contd.**Date of establishment of the S.W. monsoon along the West Coast of India—contd.*

Year	Travancore-Cochin	S. Kanara	Ratnagari	Kolaba
1918 . . . . .	May 7	May 15	May 22	May 25
1919 . . . . .	" 16	" 26	June 4	June 6
1920 . . . . .	" 27	June 2	" 6	" 6
1921 . . . . .	June 1	" 3	" 10	" 12
1922 . . . . .	May 25	May 31	" 10	" 12
1923 . . . . .	June 4	June 11	" 12	" 13
1924 . . . . .	May 31	" 3	" 10	" 12
1925 . . . . .	" 27	May 28	May 29	May 29
1926 . . . . .	" 28	June 5	June 9	June 10
1927 . . . . .	" 23	May 27	" 10	" 10
1928 . . . . .	" 31	" 31	" 5	" 7
1929 . . . . .	" 29	" 30	" 1	" 6
1930 . . . . .	" 21	June 7	" 8	" 9
1931 . . . . .	" 23	May 29	" 14	" 14
1932 . . . . .	" 14	June 2	" 3	" 3
1933 . . . . .	" 22	May 28	" 1	" 1
1934 . . . . .	June 6	June 6	" 10	" 10
1935 . . . . .	" 10	" 10	" 12	" 14
1936 . . . . .	May 20	May 22	May 29	" 1
1937 . . . . .	June 3	June 10	June 11	" 12
1938 . . . . .	" 1	" 2	" 2	" 4
1939 . . . . .	" 6	" 6	" 7	" 9
1940 . . . . .	" 7	" 13	" 16	" 18
1941 . . . . .	May 23	" 3	" 14	" 16
1942 . . . . .	June 4	" 8	" 12	" 13
1943 . . . . .	May 12	May 14	May 21	May 21

# THE SW. MONSOON

## Date of establishment

As is well known, the success of Indian agriculture depends mainly on the monsoon rains ; the farmer looks forward to the onset of the monsoon with great anxiety and prays for a timely and suitable distribution of rainfall during the season. The monsoon has been described in various publications of the India Meteorological Department. Figs. 4 and 5 show the *normal* dates of *onset* and of *withdrawal* of this monsoon in different parts of India. The actual dates of onset as well as the intensity and distribution in time and space of the monsoon precipitation vary from year to year. Table II gives the actual dates of establishment of the SW. monsoon in four areas along the west coast of the peninsula. It will be noticed that there is a considerable variation not only in the *dates* of establishment but also in the speed with which the monsoon current moves from the Travancore-Cochin area in the south towards Kolaba in the north (near Bombay). Table III below summarizes the information given in Table II.

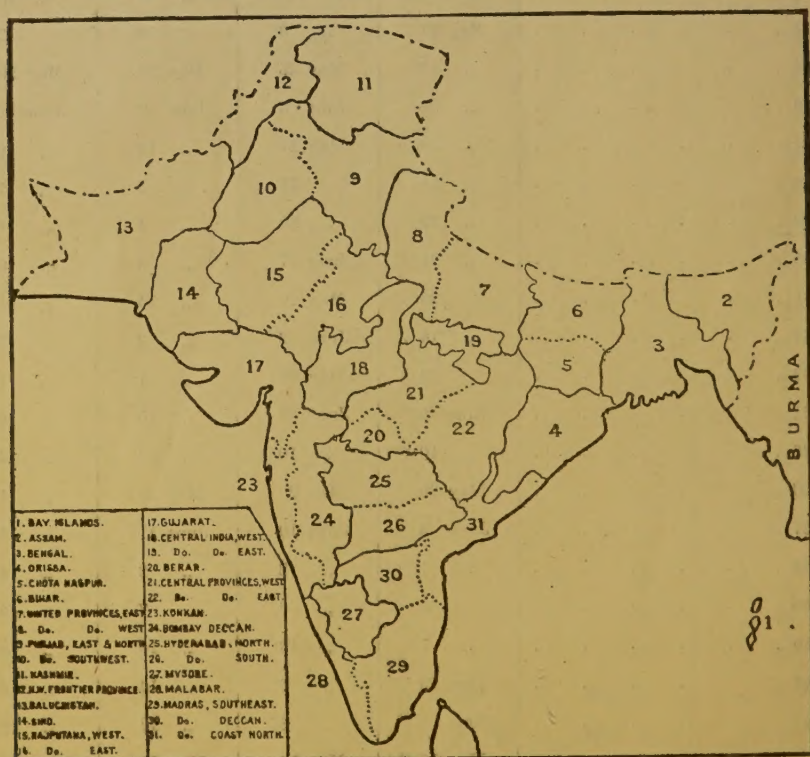


FIG. 3. Map of India showing the rainfall subdivisions

As the major agricultural operations have to synchronize with the monsoon rains, the importance of predicting the date of establishment of the monsoon in different parts of the country, the spells of rain and breaks which occur during the season, cannot be over-emphasized.

*Survey of the past 70 monsoons (1875-1944). Frequency of drought and flood years*

For this purpose the total rainfall during the period June to September is considered. If the deviation of the actual rainfall in a year is more than about twice the mean deviation, that year is defined as a year of flood or drought according as the departure is positive or negative.

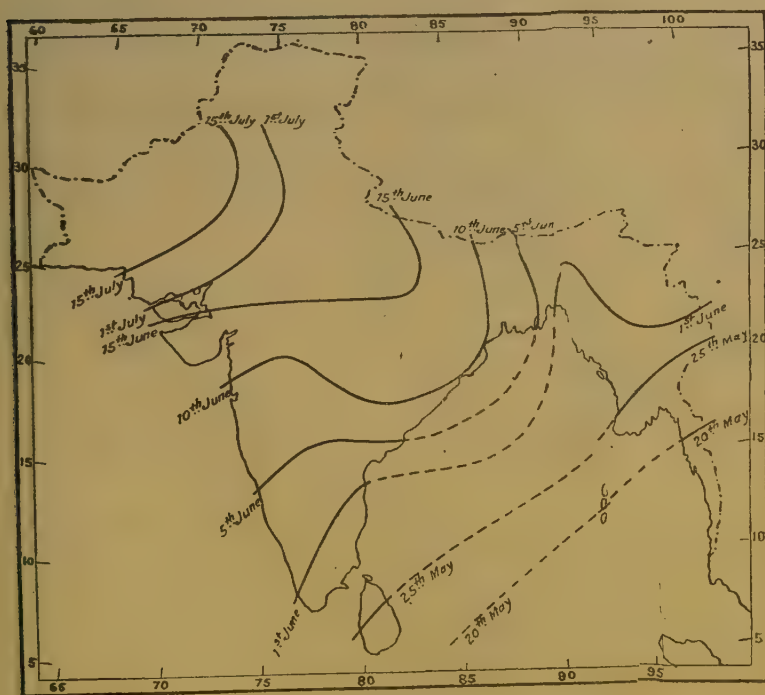


FIG. 4. Normal dates of onset of SW. monsoon

TABLE III

*Dates of establishment of the SW. monsoon along the West Coast of India*

Area	Mean date	Standard deviation (in days)	Earliest date	Latest date
Travancore-Cochin . . . . .	May 29	7.0	May 7	June 10
South-Kanara . . . . .	June 3	5.7	" 15	" 12
Ratanagiri . . . . .	" 7	5.4	" 22	" 19
Kolaba . . . . .	" 8	5.2	" 25	" 21



FIG. 5. Normal dates of withdrawal of SW. monsoon

Fig. 6 shows at a glance how the monsoon has behaved in the past 70 years in each of the 30 rainfall subdivisions of India. In the figure the filled circle indicates a flood, the open circle a drought, and the spaces which are blank are years and subdivisions with more or less normal monsoon rainfall. At the bottom of this diagram are given, for each subdivision, (1) the normal monsoon rainfall, (2) the means deviation, (3) the limit for abnormality, i.e., the amount by which the actual rainfall should be in excess or defect if it is to be labelled as 'abnormal' (flood or drought, as the case may be), (4) the total number of floods during the period 1875 to 1944, (5) the total number of droughts during the period 1875 to 1944 and (6) the total number of abnormal years (i.e. floods plus droughts) during the period 1875 to 1944.

These figures show that when we consider a sufficiently large number of years the frequencies of floods and droughts tend to equalize ; also, areas with a very low rainfall, e.g. Baluchistan, Sind, Rajputana, etc., are those where the total number of abnormalities is maximum ; in areas like the Konkan, Malabar, Bengal, etc., where the monsoon rainfall is above 40 in., the frequency of abnormal years comes down very much.

It is still more interesting to study the distribution of floods and droughts in the various subdivisions in each year. The years 1877, 1899, and 1918 stand out very prominently as years of general drought. It will be recalled that these were actually years of great famine and distress. The year 1920 was one of partial drought, only the north-west and the central parts of the country being affected. The years of general flood are 1878, 1892, and 1917. In two instances at least (1877, 1878, and 1917, 1918) droughts and floods occurred in adjacent years, but there is usually no regularity in time in the distribution of droughts and floods. The chances of one drought year being succeeded by another or a flood year being succeeded by another in a particular subdivision appear to be small. Areas of drought and floods are, however, associated into centres of defective or excessive rainfall in the years in which they do occur. For the rest, the reader can judge for himself from Fig. 6 how liable India is to the incidence of abnormal monsoons.

Before leaving this topic it will be interesting to compare the actual distributions of *weekly* rainfall during the monsoon season of the years 1917 and 1918, as they are likely to show up the contrast, not only in the total rainfall, but also in the distribution thereof. Fig. 7 shows the rainfall distribution in 1917 and 1918, for each of the main divisions : (1) NE. India ; (2) the United Provinces ; (3) NW. India ; (4) Central Provinces and Central India ; (5) North Peninsula ; (6) South Peninsula.

The dotted curves represent the normal weekly rainfall and the hatched area shows the actual rainfall. There is little contrast between 1917 and 1918 in NE. India as the rainfall was more or less normal in both the years. Over the other five divisions of the country, however, the contrast between the excess and the defect in 1917 and 1918 respectively was very marked.

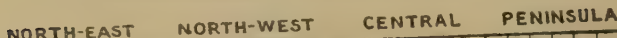


FIG. 6. Floods and droughts in India. Years of floods and droughts have for this purpose been defined as years with abnormality greater than twice the mean deviation.

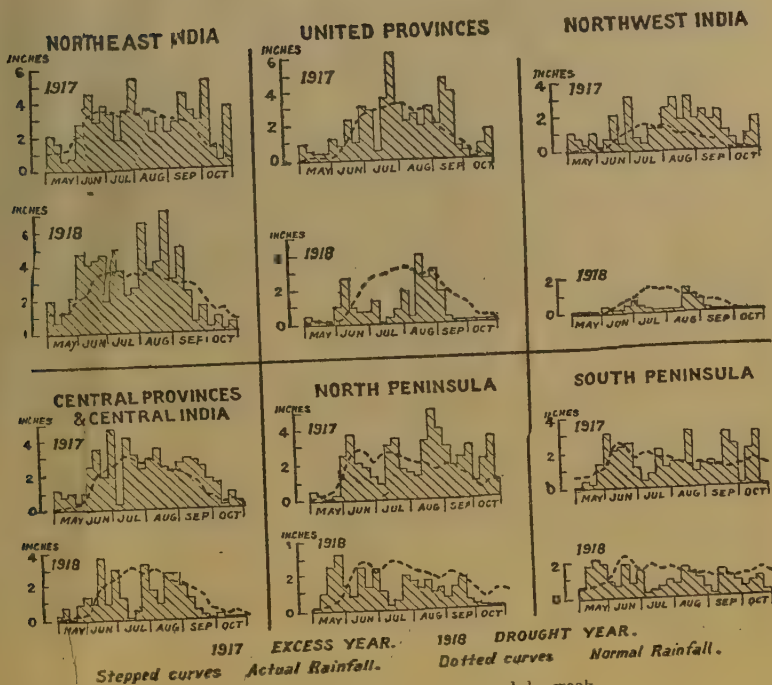


FIG. 7. Progress of the monsoon week by week

### CONTEMPORARY RELATIONSHIPS OF MONSOON RAINFALL IN FIFTEEN DIVISIONS

We have just seen that the monsoon rainfall varies from year to year both as regards the total rainfall as well as its distribution during the season. Administrators and others interested in the country as a whole may naturally inquire whether the effects of a deficiency in the monsoon rainfall in one part of the country is likely to be compensated by the effects of excess in some other part or parts.

**TABLE IV**

*Monsoon rainfall June to September. Inter-correlations between pairs of divisions.*  
(Vide Table E, Memoirs of the Ind. Met. Dept., Vol 25, Part II, p. 23)

Division	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I Burma	-0.47	-0.34	-0.05	-0.01	-0.09	-0.21	-0.29	-0.07	-0.26	+0.01	-0.01	-0.32	-0.15	-0.33
II Assam	..	+0.45	+0.27	+0.01	-0.18	-0.10	-0.13	-0.17	-0.24	-0.27	-0.40	-0.01	-0.11	+0.14
III Bengal	..	..	+0.56	-0.07	-0.07	-0.05	+0.04	-0.24	-0.31	-0.22	-0.45	-0.18	-0.15	-0.12
IV Bihar and Orissa	..	..	..	+0.31	+0.13	+0.08	+0.06	+0.05	-0.10	+0.04	-0.27	-0.01	-0.07	-0.16
V United Provinces	..	..	..	..	+0.49	+0.31	+0.06	+0.35	+0.30	+0.68	+0.33	+0.37	+0.07	+0.22
VI Punjab	..	..	..	..	..	+0.82	+0.56	+0.87	+0.50	+0.79	+0.59	+0.61	+0.11	+0.35
VII N.W.F.P.	..	..	..	..	..	..	+0.65	+0.73	+0.59	+0.64	-0.46	+0.63	+0.22	+0.45
VIII Sind	..	..	..	..	..	..	..	+0.50	+0.65	+0.34	-0.34	-0.40	-0.24	+0.40
IX Rajputana	..	..	..	..	..	..	..	..	+0.57	+0.81	-0.54	-0.37	-0.21	+0.40
X Bombay	..	..	..	..	..	..	..	..	..	+0.40	-0.58	+0.72	+0.59	+0.08
XI Central India	..	..	..	..	..	..	..	..	..	..	+0.61	+0.30	+0.50	+0.21
XII Central Provinces	..	..	..	..	..	..	..	..	..	..	..	+0.55	+0.07	+0.40
XIII Hyderabad	..	..	..	..	..	..	..	..	..	..	..	..	+0.38	+0.61
XIV Mysore	..	..	..	..	..	..	..	..	..	..	..	..	..	+0.80
XV Madras	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table IV below expresses the relation between the monsoon rainfall in each of the 15 divisions and the remaining divisions in the form of contemporary correlation coefficients. A positive coefficient in the table indicates the two areas concerned are likely to be affected similarly (i.e. both may have heavy rains in some years and deficient rains in other years). A negative coefficient would indicate that a decrease in one is likely to be associated with an increase in the other area. Looking at the correlation coefficients in each row, one notices that a vigorous monsoon over Burma tends to be associated with a subnormal monsoon over India (and *vice versa*). To a smaller extent, excessive rainfall over E. India tends to be associated with a defect elsewhere (and *vice versa*). Elsewhere, in India, i.e., NW. India, Central India, and the Peninsula, the correlation coefficients are generally positive, indicating that departures from normal are likely to be similar over the greater part of India, as indeed the dot-diagram (Fig. 6) does suggest in regard to even pronounced abnormalities like floods and droughts.

#### IS INDIA'S CLIMATE CHANGING? ARE THERE SECULAR VARIATIONS OR PERIODICITIES IN INDIAN RAINFALL?

The longest meteorological records in India are of rainfall at the cities of Madras (from 1813), Bombay (from 1847), and Calcutta (from 1829).

The rainfall data of the above station as well as of shorter series in the case of some 10 stations in Bihar were examined for periodicity. In some cases there were significant periods, but considering that neighbouring stations do not indicate similar periods, not much importance can be attached to these results. It may be worth while to examine the question more extensively for a network of selected stations or selected areas in India, for settling this point conclusively. Evidence so far collected does not, however, support the possibility of any regular periodicity in Indian rainfall.

#### OCCASIONS OF UNUSUALLY HEAVY RAINFALL

The frequency of heavy rainfall over India has been discussed in a recent note by Doraiswamy and Mohamad Zafar (*Scientific Notes*, 1, *Met. Dept.*, 7, No. 77). With reference to the heaviest fall in a day they find that

- (i) Falls exceeding 5 in. in 24 hours have occurred over the whole of India excluding NE. Baluchistan and parts of the NW. Frontier.
- (ii) Falls have not exceeded 10 in. in 24 hours over most of the interior of the Peninsula and of Burma and in a few districts in the Central parts of the country.
- (iii) Falls of 15 to 20 in. in 24 hours have occurred along the west coast including Gujerat and Kathiawar, on the Coromandel coast on the north Burma coast, in south Assam, in Bengal, and the foot of the Himalayas.
- (iv) A few isolated falls of 20 in. and over have occurred in the plains.
- (v) The greatest fall of over 40 in. in 24 hours has occurred at Cherapunji in the Khasi hills.

When heavy rainfall occurs consecutively on a number of days and particularly over the catchment areas of rivers, the magnitude of the ensuing floods may well be imagined. Rameshkrishnan (*Scientific Notes, Ind. Met. Dept., 7, No. 74*) has estimated the total volume of water precipitated over certain areas in South India on days when they were under the grip of storm coming from the Bay of Bengal. The values given by him for one of these storms are quoted below:

Date	Area on land which had rain of 0.5 in. and more in sq. km.	Volume of water precipitated on land in cu. km.
21.10.30	60,150	1.9
22.10.30	53,730	1.6
23.10.30	71,540	4.9
24.10.30	103,660	8.0
25.10.30	133,740	6.5
26.10.30	141,620	7.1
27.10.30	342,520	11.9

Increasing forest-cover, checking erosion, delaying flood-peaks, and training the major rivers, etc., are problems which have begun to demand an increasing attention of the State.

#### REGIONAL PECULIARITIES IN DISTRIBUTION OF RAINFALL: CLIMATIC HOMOGENEITY

Even if we divide the country into climatically homogeneous tracts, judging from the normal rainfall they are still outstanding local peculiarities. This may be emphasized with the aid of a few examples.

Suppose that a weather forecaster expects a particular subdivision in the country to come under the influence of disturbed weather and forecasts rainfall over the area. Can he expect all rain-gauge stations to record more or less similar rainfall during a particular day? Or will the rainfall be very variable? This involves the question of rainfall variability in space and is very important from the weather forecaster's point of view.

We may also consider the point of view of an irrigation engineer faced by the problem of constructing reservoirs to serve the agriculturist's needs. Should he construct one big reservoir at a likely place or should he scatter a series of small reservoirs, casting a wide net, so that one or the other of the reservoirs collects such rainfall over its neighbourhood? How would the variability between stations in a given area compare with the variability between days of a month and with the variability due to random chance?

In connexion with a recent inquiry, the variability of rainfall in the month of July 1942 was analyzed for a number of representative areas in India, taking 20 stations selected at random from each of these areas. Table V gives the analysis of variance between 'stations', days of the month, and 'residual' (due to random variability), for the Punjab, the United Provinces, the Central Provinces, Bengal, Rajputana, and Malabar. Column (5) gives the standard deviation of the variability 'between stations,' 'between days', and 'residual' or error. The next column gives the ratios of the variances, i.e.

$$\frac{\text{Variance between stations}}{\text{residual variance}} \quad \text{and} \quad \frac{\text{Variance between days}}{\text{residual variance}}$$

TABLE V

*Analysis of variance of rainfall in July 1942*

Due to	Degrees of freedom	Sum of squares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability per cent.
<b>1. The Punjab</b>							
Stations . . . . .	19	21-1834	1-1123	1-55	3-73*	0-228 in.	680
Days . . . . .	30	19-8421	0-6614	0-81	2-22*	..	566
Residue . . . . .	570	169-8981	0-2981	0-55	..	..	241
TOTAL . . . . .	619	210-8736	0-3407	..	..	..	..
<b>2. The United Provinces</b>							
Stations . . . . .	19	16-1105	0-8479	0-92	1-55	0-466 in.	197
Days . . . . .	30	114-5280	3-8148	1-95	6-97*	..	418
Residue . . . . .	570	812-1042	0-5475	0-74	..	..	159
TOTAL . . . . .	619	442-7427	..	..	..	..	..
<b>3. The Central Provinces</b>							
Stations . . . . .	19	45-5754	2-8987	1-55	1-35	0-697 in.	222
Days . . . . .	30	270-4394	9-1465	3-02	5-16*	..	433
Residue . . . . .	570	613-9953	1-7715	1-33	..	..	191
TOTAL . . . . .	619	929-9901	1-5024	..	..	..	..

\* Means significant at 1 per cent level

TABLE V—*contd.**Analysis of variance of rainfall in July 1942.*

Due to	Degrees of freedom	Sum of squares	Mean square (variance)	Standard deviation	Variance ratio : 'F'	Rainfall per day	Coefficient of variability per cent.
<b>4. Bengal</b>							
Stations . . . . .	10	41.4545	2.1818	1.48	3.62*	0.422 in.	350
Days . . . . .	30	43.2902	1.4430	1.20	2.39*	..	284
Residue . . . . .	570	343.4197	0.6025	0.78	..	..	185
TOTAL . . . . .	619	428.1644	0.6917	..	..	..	..
<b>5. Rajputana</b>							
Stations . . . . .	19	108.8973	5.7314	2.39	6.92*	0.417 in.	573
Days . . . . .	30	46.2551	1.5418	1.24	1.86	..	297
Residue . . . . .	570	471.9398	0.8280	0.91	..	..	218
TOTAL . . . . .	619	627.0922	1.0131	..	..	..	..
<b>6. Malabar</b>							
Stations . . . . .	19	85.4648	4.4981	2.12	5.53*	1.331 in.	159
Days . . . . .	30	382.1749	12.7392	3.57	15.68*	..	288
Residue . . . . .	570	463.1872	0.8126	0.90	..	..	68
TOTAL . . . . .	619	930.8269	1.5038	..	..	..	..

\* Means significant at 1 per cent level

If the variability 'between stations', 'between days', and 'residual' are all of the same order of magnitude the ratio  $F$  will not be significant.

In the Punjab, Bengal, and in particular Rajputana and Malabar, the variability between stations is very significantly larger than that caused by random chance. In Malabar this variability is due to orography, whilst in Rajputana it represents a real climatic non-homogeneity. The variability between days is significant in all cases. In places like Rajputana it is indeed difficult to indicate where exactly rain would fall during a wet spell. The engineer would be well advised to construct a wide network of tanks in preference to a single big tank in such tracts.

#### IRRIGATION WORKS AND LARGE-SCALE RESERVOIRS, BUNDS, ETC.

Wherever the precipitation falling over a very wide catchment is drained into large river-systems like the Indus and Ganges, it is obvious that irrigation projects will be successful, as has indeed happened in the Punjab and Sind. In the United Provinces, besides canal irrigation, tube-wells are also being sunk on a large scale.

It may be pointed out that the large dry tracts of Peninsular India which are not fed by rivers can get adequate supplies of water for agriculture if the necessary irrigation-projects are set up at suitable localities in the catchment areas of the Western Ghats *which receive sufficient rains for this purpose even in years with weak monsoons*. Much of this water is now drained by rapids flowing into the Arabian Sea. If large reservoirs are built up on the Ghats over elevated areas, taking advantage of natural facilities for impounding the rain-water, the water so collected can be fed into the plains to the east of the Ghats through canal systems. This is a problem which the State alone can tackle ; it is full of large potentiality for the future of the arid tracts of Peninsular India.

In concluding this all too brief a summary of India's rainfall as affecting its agricultural potentialities, it may be appropriate to state that the India Meteorological Department is undertaking, in the very near future, to broadcast special weather bulletins and forecasts for the farmer. Seven Regional Forecasting Centres have been started. These will cater for the special weather requirements of their respective regions. Warnings for heavy and untimely rainfall, heat waves, cold waves, droughts, hail-storms, high winds, etc. will be issued, keeping in view the needs of the important crops of each region. In this new undertaking the Agricultural Meteorologist will maintain a close liaison between agriculture and meteorology.



## PRELIMINARY STUDIES ON THE ESTABLISHMENT OF COLOUR STANDARDS IN RELATION TO SOIL CONSTANTS

By A. G. ASGHAR, C. L. DHAWAN and K. D. BHOLA, Irrigation Research Institute,  
Punjab, Lahore

(Received for publication on 18 June 1947)

(With four text figures and plate I)

**F**ROM the point of view of a cultivator, soil colour is regarded to be the first important characteristic of a soil. An average farmer judges the quality of a soil from the colour of the soil, and his verdict as to its usefulness for agricultural purpose or otherwise is primarily based on this observation.

The property of soil colour has now found its place in scientific research, and some work has been accomplished during the last few years in this direction. The treatment of the subject on a scientific basis has been done by developing various methods of measurements. The Soil Colour Standards Committee of the American Soil Survey Association found that nearly all the soils could be reproduced by rotating a colour disc containing the black, yellow, red and white segments. Hutton [1927] rotated the colour segments at high speed in a horizontal plane and held the soil over the rotating disc on a broad bladed spatula or in a small dish. This method was further improved by Shaw who rotated the soil on the same spindle as the colour disc.

For field descriptions of the soils, the United States Division of Soil Survey adopted a series of 57 standard colour names and colour charts describing these classes. These charts obviated the matching of the colour of the soil-sample with the colour discs and recommended the use of C.I.E. (Commission International *d*, Echirage) in the standardization of the soil colour values. Recently spectroscopy has also been introduced in measuring soil colour.

Attempts have been made to correlate the chemical composition of the soil and the soil colour. Mest [1910] and Leather [1898] attributed the black colour to titaniferous magnetite and humus. While Harrison and Rama Swami Sivan [1912] attributed it partly to humus and partly to hydrated double silicates of iron and aluminium. Ferrous oxide has no influence on soil colour and that it depends upon the silica ferric oxide ratio in the hydrochloric acid extract of the soil and that the red soil contains more ferric oxide and the black soil more of silica. Sante-Mattson [1941] has observed that soil colour may not be regarded as a sort of pigment present in the soil but a definite indication of constitutional differences in the composition and characteristics of the soil which are the result of lithospheric, atmospheric, hydrospheric and biospheric influences.

It will be seen from the literature referred to that during the past years the soil workers have been mostly engaged in the standardization of the methods for measuring the soil colour and to correlate the colour with the chemical composition of the soil. But no work has so far been carried out to correlate the soil colour with the soil performance and soil characteristics. The present investigation deals with the results of statistical analysis in an effort to correlate the soil colour and the physico-chemical properties of soils.

### EXPERIMENTAL

An electrically rotating disc composed of segments of black, white, red and yellow standard colours, on thick paper, the speed of which could be adjusted by the help of rheostat was used for the comparison of the colours. Circular paper discs were so fixed by means of a screw in the centre of the disc that the area of any one colour could be adjusted suitably. A brass disc of 2.8 in. diameter was adjusted in the centre of the revolving disc. The soil to be tested was placed on this brass disc according to the following procedure.

A preliminary standardization of the method of preparing soil disc was necessary as is usually done in the case of chemical analysis. The soil was dried and sieved through 50 mesh sieve i.e. 0.25 mm. diameter and taken in a dish one day before the test was to be carried out. Water was added to make a thin paste and allowed to remain over-night. Next day the soil paste was applied gently with a brush to a semi-wet paper. The paste was allowed to dry under ordinary atmospheric conditions, and the soil coated paper so formed was pressed between two glass slabs. A disc of convenient size was then cut out, and a hole punched in the centre. The soil disc was mounted on the colour disc in the centre and kept in position by the help of the central screw. The colour disc having the soil disc was then rotated at a predetermined constant speed. During the rotation the soil disc developed a smooth colour. The segments of the colour disc were adjusted so that the soil disc exhibited the similar colour. The readings of the colour segments were taken on the circular dial which was graduated in angular degrees. Plate I shows the position of soil colour disc at rest and in motion. The soils were examined for clay, sticky point exchangeable bases, available phosphate and calcium carbonate by Puri's methods [1930, 1935]. The pH values were determined by the glass electrode using 1 : 5 soil water ratio.

### *Soil-sampling*

Soil-samples (from 0-1.0 ft.) were collected from the various parts of India representing different types i.e. clay loam, lateritic, black cotton, forest soil, alkaline, and saline.

\* \* \* \* \*

### *Diagrammatic representation of analytical results*

To facilitate comparison the results of analysis have been represented graphically. The results of clay, sticky point and exchangeable calcium have been plotted (vide Figs. 1-4).

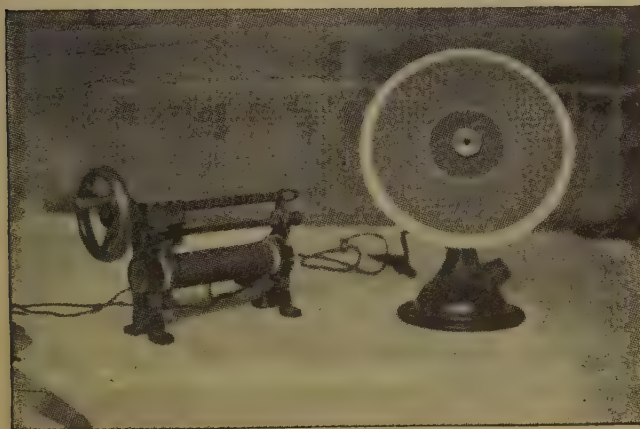


FIG. 1. Soil Colour Disc in motion.

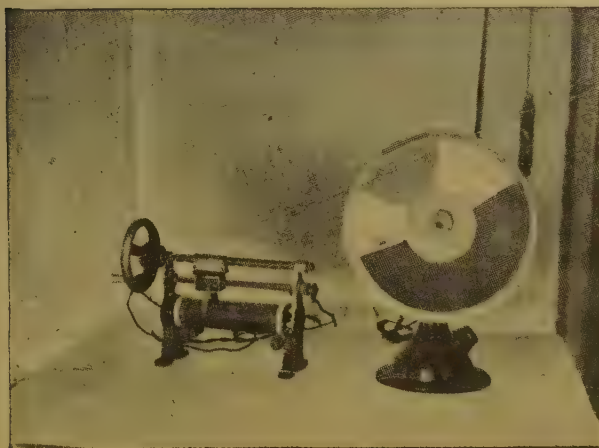


FIG. 2. Soil Colour Disc at rest.



\* \* \* \* \*

*Statistical treatment of analytical analysis*

\* \* \* \* \*

The statistical analysis of the observations is given in Table I. The following are the notations used in the statistical interpretation of the analytical results.

Variable 1	.	.	Soil colour readings in degrees.
Variable 2	.	.	Analytical results for the characteristic under consideration e.g. clay or sticky point etc. etc.
r 12	.	.	Total correlation between variable 1 and 2.
A 12	.	.	Percentage variance of soil colour expressible in terms of variable 2 alone.

DISCUSSION OF RESULTS

1. *Correlation of clay content and soil colour*

Fig. 1 shows the relation between the clay content and the black colour. The correlation between clay content and black colour is significant. The correlation coefficient is 0.6090, and positive. It shows that high clay content is associated with high black colour reading on the colour disc. The other colours do not bear any correlation with the clay content.

2. *Correlation of sticky point and soil colour*

The relation between the red colour and the sticky point is plotted in Fig. 2. The correlation with the sticky point is 0.7165 and negative. This shows that the high red colour is a characteristic of low sticky point. There is no correlation with the other colours.

3. *Correlation of exchangeable calcium and soil colour*

The relation between the black and red colours and the exchangeable calcium are represented in Figs. 3, 4. The correlation coefficients of exchangeable calcium with black and red colour are 0.7439 and positive and 0.3232 and negative respectively. The high black colour signifies high exchangeable calcium and the high red colour low exchangeable calcium. The correlation with the red colour is not very significant. It is interesting to note that the correlations of the black colour with the clay content and exchangeable calcium are positive in both the cases.

4. *Correlation of pH calcium carbonate, available phosphate and exchangeable (sodium+potassium) with soil colour*

There is no correlation with any of the above constants.

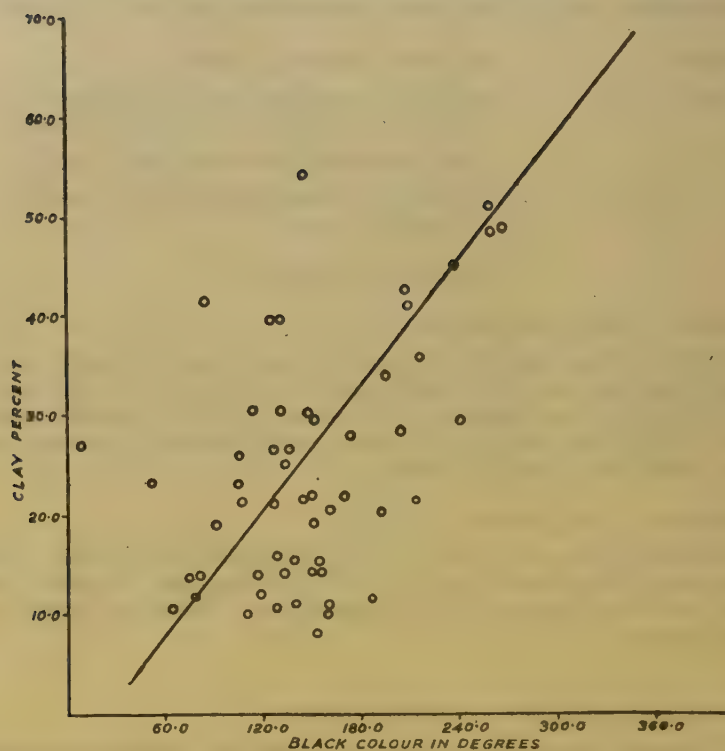


FIG. 1. Relation between clay and black colour

The regression equation is :

$$y=0.14x+5.3$$

where  $x$ =Black colour reading

$y$ =Clay percentage

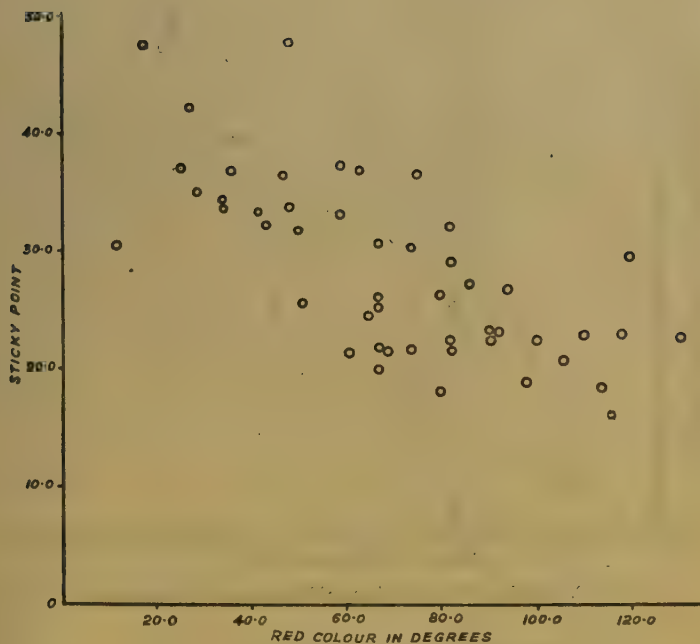


FIG. 2. Relation between sticky point and red colour

The regression equation is :

$$y = -0.19x + 41.3$$

where  $x$  = Red colour reading

$y$  = Sticky point

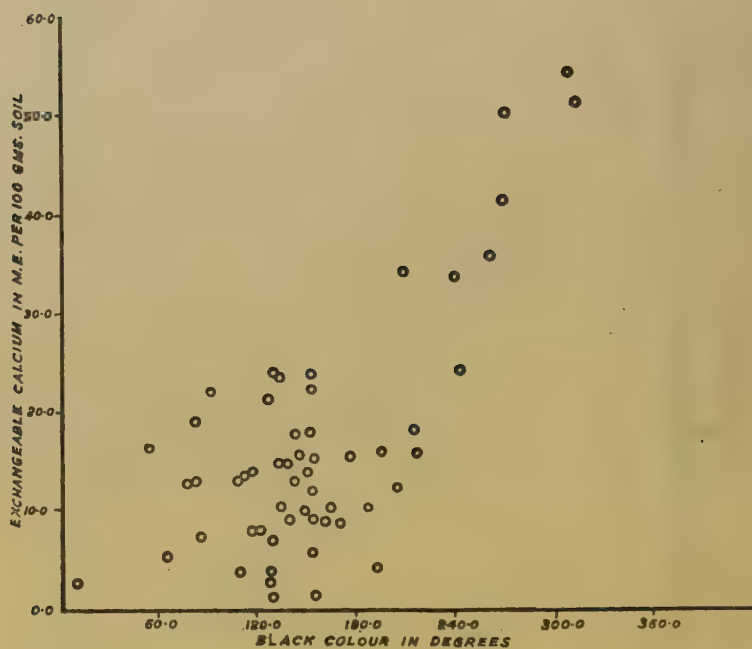


FIG. 3. Relation between exchangeable calcium and black colour

The regression equations are ;

$$y = 0.15x - 6.9$$

$$Y_1 = -0.13x_1 + 26.4$$

where X = Black colour reading

$X_1$  = Red colour reading

and Y and  $Y_1$  = Exchangeable calcium

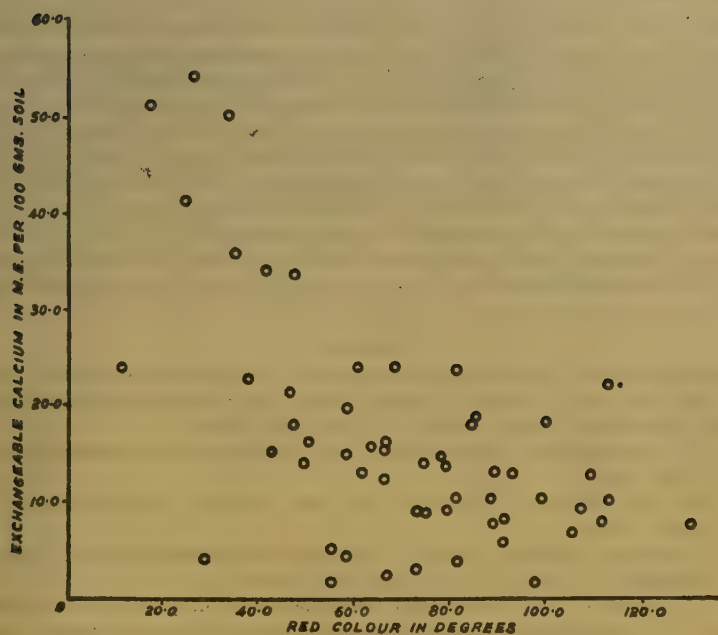


FIG. 4. Relation between exchangeable calcium and red colour

5. *Mutual correlation between clay and exchangeable calcium of the soils*

It has been shown above that there exists very significant correlation between the clay and exchangeable calcium content of soils with black colour. It is most probable that the characteristics which give significant correlation with black colour might have a correlation between themselves. It was therefore considered desirable to determine the mutual correlation of clay and exchangeable calcium contents of soils. The mutual correlation coefficient is 0.7892 and positive, which is highly significant. It indicates that a high exchangeable calcium is associated with a high clay content.

6. *Partial correlation coefficient between black colour and clay and exchangeable calcium*

It has been stated that the black colour is correlated with clay content and exchangeable calcium, and that the last two characters are correlated among themselves. The partial correlation coefficient between the two characters will therefore give us an idea of the association between two characters where the effect of the third is eliminated. The partial correlation coefficient between black colour and the clay content when the effect of exchangeable calcium is eliminated is .0529 and the partial coefficient between black colour and the exchangeable calcium is 0.5404. In order to test the significance the values of  $t$  were calculated. The value of  $t$  for the former is 0.3749, which is insignificant and for the later is 4.542 which is significant. This shows that the black colour is independent of the clay and depends upon the exchangeable calcium.

## SUMMARY

The examination of the analytical data by the method of correlational analysis shows that significant correlation exists between clay and exchangeable calcium and black colour and between sticky point and red colour.

2. The correlation of exchangeable calcium with red colour though significant is not of high order.

3. The black colour is independent of clay content but depends upon the exchangeable calcium.

4. There is no correlation between pH, calcium carbonate, available phosphate and exchangeable Sodium-potassium with any colour.

5. As a result of this investigation the importance of the soil colour standard in relation to the physico-chemical properties of the soil has been brought out.

TABLE I

*Correlations between soil colour and certain soil characteristics*

Soil characteristics	Soil colour	No. of observation	r 12	A 12
Clay content	Black . . . .	53	+0.6090	35.86
Sticky point	Red . . . .	47	-0.7165	50.23
Exchangeable calcium	Black . . . .	56	+0.7439	54.52
Exchangeable calcium .	Red . . . .	56	-0.3232	8.80

REFERENCES

- Harrison & Rama Sawami Sivan (1912). *Mem. Dep. Agric. Ind. Chem.* **2**, 261
- Hutton, J. G., (1927). *Proc. 1st Int. Congr., Soil Science* **4**, 164-162
- Leather, J. W., (1898). *Agric. Ledger* (No. 20098)
- Matteson Sante, (1941). *Soil Science* **51**, 408
- Mest A., N. E., (1910). *Mem. Dep. Agri. Ind. Chem.* **185**
- Puri, A. N., (1936). Dispersion of Soil for mechanical analysis by Sodium Carbonate or Sodium Oxalate treatment. *Soil Science* **42**, 287
- Puri, A. N., (1930). A new method of determining 'Sticky point' in soils—*Indian J. Agric. Sci.* **1**
- Puri, A. N., (1935). Estimation of Replaceable Na and K, Exchange—capacity, and degree of alkalization in alkali soils by Ammonium carbonate extractions—*Soil Science* **40**, 249
- Puri, A. N., (1935). A new method of estimating exchangeable bases in soils—*Soil Science* **40**, 149
- Puri, A. N., Asghar, A. G., (1936). Estimating available phosphates in soils by carbon-di-oxide extraction—*Soil Science* **42**, 39
- Puri, A. N., (1930). 'A new method of estimating total carbonates in Soils' *Imp. Coun. Agri. Res. India, Bull No.* **206**



# STUDIES ON BUNDELKHAND SOILS OF UNITED PROVINCES

## III. PEDOCHEMICAL CHARACTERISTICS OF THE BLACK SOILS OF THE PLAINS

By R. R. AGARWAL, M.Sc., D. PHIL., Agricultural Chemist, Government of United Provinces, and P. MUKERJI, B.Sc.(Ag.), Assoc. I.A.R.I., Dry Farming Officer, U. P.

(Received for publication on 5 December 1947)

IN previous communications [Mukerji and Agarwal, 1943 ; Agarwal and Mukerji, 1946] the soils of the district of Jhansi in the Bundelkhand tract have been described in detail from the stand-point of their genesis and three soil types differing from one another in general chemical, physical and mechanical characteristics were recognised. The district of Jalaun forms the most northerly portion of the tract and its landscape is entirely different from what one finds in the other parts of Bundelkhand. The district is a wide flat basin containing no hills but encircled by narrow rims of higher ground. The entire basin is covered with fertile black soil.

The black soils are known to be calcareous, friable and very retentive of moisture. The fertility is reputed to be high since crops of mixed wheat and gram are grown year after year without any manure or irrigation. The soils are, however, exposed to peculiar dangers due to their adhesiveness and unusual capacity to retain moisture. They become saturated with water quickly and when this happens tillage operations are very difficult. Besides, the black soil expands and contracts in a remarkable degree under the influence of moisture and dryness opening out into large fissures at frequent intervals.

Geologically the origin of these soils is ascribed to the subaqueous decomposition of trap rocks, but it has also been believed that it may really be due to subaerial denudation of basaltic rocks and the impregnation of certain argillaceous soils by organic matter the latter ingredient together with iron giving it its black colour [Drake-Brokeman, 1910].

### *Agriculture*

The agricultural system of the district though not of a high order excels in a general way the average of Bundelkhand. There are no irrigation facilities and all cultivation is done under dry farming conditions. The chief *kharif* crops are *juar* and *bajra* alone or mixed with *arhar* and cotton. Of late the area under cotton has decreased considerably. *Juar* is the only staple *kharif* crop of Bundelkhand black soils. The chief *rabi* crops are gram and wheat, alone or mixed with one another. Linseed is also sown generally in fringes in the wheat fields.

*Climate*

The climate of the district is very similar to that of Bundelkhand, details about which have already been described in part I of the series. The rainfall is slightly less than what is generally received at Jhansi. Records of rainfall have been maintained at the tehsil headquarters since 1864. Average figures for the three tehsils are given in Table I.

TABLE I  
*Average monthly rainfall data for Jalaun*  
(Average of 47 years in inches)

Tehsil	January	February	March	April	May	June	July	August	September	October	November	December	Total
Jalaun . . .	0.50	0.42	0.29	0.14	0.33	3.17	10.24	10.49	4.99	0.82	0.07	0.25	31.61
Kunch . . .	0.56	0.29	0.17	0.13	0.26	3.02	11.40	10.14	4.79	0.64	0.09	0.23	31.72
Orai . . .	0.52	0.35	0.12	0.12	0.25	3.63	10.48	10.45	4.69	0.74	0.07	0.21	31.63
Average . . .	0.53	0.35	0.19	0.13	0.28	3.27	10.71	10.36	4.82	0.67	0.08	0.23	31.65

The mean annual rainfall is 31.65 inches there being very little difference among the three tehsils. The precipitation is, however, very variable and this makes the agriculture of the tract most precarious. For, a deficient rainfall which brings about famine conditions is as disastrous as excessive rainfall in black soils. The months of June, July, August and September are the months which get most of the yearly precipitation, viz., about 29 inches. Only 2.65 inches are received in the remaining part of the year.

A careful survey of the soils of the areas which may be considered to be typical of the locality was made. Two soil profiles which were studied in detail are described in this paper. The samples of soil were collected horizon-wise. Morphological, chemical, mechanical and other data are presented in the body of the paper. The technique and the methods of analysis employed were the same as those described in part I of this series. Free iron in clay was estimated by the modification of Truog's method [1936] as suggested by Drosdoff [1941].

## EXPERIMENTAL

Of the two soil profiles which were sampled for detailed investigations, one was from a pit dug on the Government Cattle Farm at village Ata in tehsil Orai and the other at village Satoh in tehsil Konch. Both the profiles were obtained from cultivated fields in which cultivation is being done without any irrigation or manure. The water table is about 80 to 90 feet below the surface and the texture of the soil is reported to be clayey.

Table II contains the morphological characters of the two profiles

TABLE II

*Morphological characters of the soil profiles*

Horizon	Depth	Sample depth	Description
<i>Ata profile</i>			
I	0 ft.-1 ft.	0 ft.-1 ft.	Black sticky soil tending to become ash grey on drying ; no structure, compact, alkaline but non-calcareous
II	1ft.-3ft. 6in.	1ft.-2ft. 4in. 2 ft. 4 in.- 3 ft. 6 in.	Same as above ; slightly calcareous ; more alkaline
III	3ft. 6in.-5ft.	3 ft. 6 in.- 4 ft. 8 in. 4ft. 8in.-5 ft.	Ash grey tending to appear white ; not so compact ; less clayey than above ; more alkaline and calcareous
IV	5 ft.-6 ft.	5 ft.-6 ft.	Calcareous ; distinctly alkaline ; loosely held calcareous material
<i>Satoh profile</i>			
I	0 ft.-2 ft.	0 ft.-1 ft. 1 ft.-2 ft.	Black sticky soil becoming grey on drying ; no marked structure ; compact, alkaline ; no effervescence with hydrochloric acid
II	2 ft.-4 ft.	2 ft.-3 ft. 3 ft.-4 ft.	Same as above, darker in tinge ; alkaline ; slightly more compact ; does not effervesce with hydrochloric acid
III	4 ft.-6 ft.	4 ft.-5 ft. 5 ft.-6 ft.	Slightly more alkaline, somewhat loose but clayey ; very slight effervescence with hydrochloric acid

The profiles show all the characteristics of calcareous black soils. There are no clear cut horizon differences but the distribution of lime is slightly greater in bottom layers. The texture of the soil is predominantly clayey although the sub-soils are not so compact as the top layers. Nowhere, however, this compactness confers on the horizons an indurated character. The reaction throughout is alkaline although the bottom layers are more alkaline than the top layers.

In Table III are given the results of the analysis of the hydrochloric acid extracts of the soil samples from the two profiles.

TABLE III

*Analysis of the hydrochloric acid extract*

(Per cent oven dry basis)

*Ata profile*

Particulars	0 ft.-1 ft.	1 ft.- 2 ft. 4 in.	2 ft. 4 in.- 3 ft. 6 in.	3 ft. 6 in.- 4 ft. 8 in.	4 ft. 8 in.- 5 ft.	5 ft.-6 ft.
Loss on ignition . . .	3.59	3.64	3.47	2.14	2.42	2.54
Total insolubles . . .	73.89	73.38	73.79	68.00	70.21	69.63
Sesquioxides . . .	16.16	16.82	14.71	14.75	14.25	14.47
Fe <sub>2</sub> O <sub>3</sub> . . . . .	5.90	6.03	5.92	5.73	5.87	5.96
Al <sub>2</sub> O <sub>3</sub> . . . . .	10.26	10.78	8.78	9.02	8.38	8.51
CaO . . . . .	2.18	2.51	2.79	5.75	5.30	5.36
MgO . . . . .	2.05	2.02	2.01	2.54	2.42	2.35
K <sub>2</sub> O . . . . .	2.29	2.35	1.16	2.26	2.20	0.80
P <sub>2</sub> O <sub>5</sub> . . . . .	0.052	0.070	0.083	0.123	0.102	0.112
CO <sub>2</sub> . . . . .	0.69	0.90	1.29	2.67	2.60	2.96

*Satch profile*

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-5 ft.	5 ft.-6 ft.
Loss on ignition . . .	4.21	4.05	4.48	4.08	3.91	4.15
Total insolubles . . .	74.71	73.53	75.84	72.28	72.57	73.41
Sesquioxides . . . . .	16.07	16.95	15.53	17.83	17.03	14.80
Fe <sub>2</sub> O <sub>3</sub> . . . . .	6.05	6.35	6.48	6.41	6.43	6.34
Al <sub>2</sub> O <sub>3</sub> . . . . .	10.01	10.59	9.15	11.41	10.59	8.46
CaO . . . . .	1.83	1.63	1.77	1.85	1.77	1.71
MgO . . . . .	0.75	0.98	0.84	1.85	1.74	1.01
K <sub>2</sub> O . . . . .	0.92	1.02	0.92	0.97	1.06	1.45
P <sub>2</sub> O <sub>5</sub> . . . . .	0.116	0.095	0.117	0.106	0.116	0.095
CO <sub>2</sub> . . . . .	0.29	0.54	0.59	0.90	0.35	0.50

Moisture (not given in the Table) is more or less uniform throughout the profile except in the fourth layer in Ata profile and in the first layer in Satoh profile where it is slightly less in comparison. In the Ata profile the loss-on-ignition figures are constant in the first three layers and the next three layers show somewhat lower losses. In the Satoh profile loss-on-ignition figures are within limits constant. This shows that the distribution of colloidal matter is almost uniform in both the profiles. Acid insolubles do not also differ much with depth, only the top layers are slightly richer in these constituents. In regard to sesquioxides, the distribution of iron is uniform throughout although in the Ata profile alumina is more in the top two layers as compared with the bottom layers. Alumina is also slightly lower in the third and the sixth layer in comparison with other layers of the Satoh profile. Alkaline earth metals show some evidence of leaching. Both lime and magnesia have migrated to the bottom layers in the case of the Ata profile whereas only magnesia leaching is visible in the case of Satoh profile. The potash distribution is more or less uniform although there is more potash in the lower layers in Satoh profile. The Ata profile contains in general much more potash than the Satoh profile.  $P_2O_5$  content is poor in both the profiles there being some evidence of phosphate leaching in the Ata profile. In general, the chemical composition of the soil material does not seem to vary much with the depth of the profile showing thereby that the forces of soil decomposition and consequent deposition have been extremely poor under the climatic conditions prevailing in the district.

The results of the mechanical and other general analyses are given in Table IV.

TABLE IV

*Mechanical analysis (2 mm. sample) and general analysis*

(Per cent air dry basis)

*Ata profile*

Particulars	0 ft.-1 ft.	1 ft.- 2 ft. 4 in.	2 ft. 4 in.- 3 ft. 6 in.	3 ft. 6 in.- 4 ft. 8 in.	4 ft. 8 in.- 5 ft.	5 ft.-6 ft.
Coarse sand	0.270	0.675	1.78	1.45	1.00	2.08
Fine sand	27.34	24.21	24.77	27.79	30.44	30.96
Silt	24.00	28.00	28.00	23.75	22.75	24.00
Clay	40.50	36.25	35.25	33.50	33.00	31.50
pH in N KCl	7.8	7.3	7.8	8.2	8.4	8.4
Total nitrogen	0.071	0.059	0.057	0.048	0.043	0.042
Organic carbon	0.261	0.255	0.241	0.134	0.114	0.127
C/N ratio	3.7	4.3	4.2	2.8	2.6	3.0

TABLE IV—*contd.**Mechanical analysis (2 mm. sample) and general analysis*

(Per cent air dry basis)

*Satoh profile*

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-5 ft.	5 ft.-6 ft.
Coarse sand	0.62	1.08	0.65	2.61	0.54	2.45
Fine sand	24.29	23.53	22.55	21.90	22.58	22.04
Silt	28.25	28.50	27.50	27.25	27.50	24.25
Clay	44.00	44.00	45.00	44.25	45.75	46.25
pH in N KCl	7.6	7.6	7.6	8.0	7.8	7.8
Total nitrogen	0.041	0.039	0.053	0.045	0.048	0.067
Organic carbon	0.285	0.030	0.291	0.300	0.316	0.300
C/N ratio	6.9	7.7	5.5	6.7	6.6	4.5

Both the soil profiles exhibit highly clayey texture. Clay content varies from 40 to 44 per cent in the top layers. In general, the textural variation in the profile has not been much showing thereby the absence of even physical translocation of the soil material. The low rainfall of the locality coupled with the calcareous nature of the soil has made it almost impossible for the clay to migrate to lower depths. In the Ata profile the clay content is more in the top layers as compared with the bottom layers. Reverse is the case with the coarse sand content. pH increases with depth in Ata profile due to the presence of carbonates of lime and magnesia. This increase is not pronounced in the case of the Satoh profile. The pH of the surface layers is, however, not very alkline. Total nitrogen content is not high but is more as compared to organic carbon giving narrow C/N ratios in the soil profile.

The nature of the exchange complex of the soil profile is shown by the figures of the exchangeable bases given in Table V.

TABLE V

*Exchangeable bases**m. e. per cent**Ata profile*

Particulars	0 ft.-1 ft.	1 ft.- 2 ft. 4 in.	2 ft. 4 in.- 3 ft. 6 in.	3 ft. 6 in.- 4 ft. 8 in.	4 ft. 8 in.- 5 ft.	5 ft.-6 ft.
Calcium . . . . .	29.36 (77.02)	23.68 (62.3)	17.12 (49.34)	10.32 (38.77)	9.20 (39.86)	8.00 (34.95)
Magnesium . . . . .	6.22 (16.32)	10.12 (26.62)	10.93 (31.50)	9.23 (34.67)	6.23 (26.99)	7.78 (33.99)
Potassium . . . . .	2.21 (5.80)	2.21 (5.82)	2.65 (7.64)	1.77 (6.65)	2.65 (11.48)	2.21 (9.66)
Sodium . . . . .	0.33 (0.86)	2.00 (5.26)	4.00 (11.53)	5.30 (19.91)	5.00 (21.66)	4.90 (21.40)
Total exchangeable bases .	38.12	38.01	34.70	26.62	3.08	22.89

*Satoh profile*

Particulars	0 ft.-1 ft.	1 ft.-2 ft.	2 ft.-3 ft.	3 ft.-4 ft.	4 ft.-5 ft.	5 ft.-6 ft.
Calcium . . . . .	32.80 (82.72)	33.28 (81.49)	32.00 (78.64)	32.16 (80.68)	31.52 (77.59)	30.24 (74.73)
Magnesium . . . . .	3.46 (8.73)	3.38 (8.27)	5.24 (12.88)	4.16 (10.44)	5.71 (14.07)	6.99 (17.27)
Potassium . . . . .	1.76 (4.44)	2.42 (5.93)	1.98 (4.87)	1.98 (4.96)	1.76 (4.33)	1.54 (3.80)
Sodium . . . . .	1.63 (4.11)	1.76 (4.31)	1.47 (3.61)	1.56 (3.92)	1.63 (4.01)	1.70 (4.20)
Total exchangeable bases .	39.65	40.84	40.69	39.86	40.62	40.47

(Figures in brackets show percentage of the total exchangeable bases.)

A study of the distribution of the exchangeable bases in the soil profile clearly shows the calcium nature of the soils. Throughout, the predominating cation in the complex is calcium. Calcium and magnesium together constitute about 90 per cent of the total exchangeable bases in the Satoh profile. In the Ata profile the top two layers contain about 90 per cent of the divalent bases but the lower layers are richer in mono-valent ions. Calcium has a tendency to decrease and magnesium to increase downwards in the profile. In the Ata profile sodium concentration is very high in the bottom layers although the top two layers are not so rich in that base. Both sodium and potassium are more or less constant being in

moderately low quantities in the Satoh profile. It appears that the exchange complex of the soils is inherently rich in calcium but that there is some danger of its getting sodiunised specially in the bottom layers as has been found in the Ata profile.

The separated clay fraction was analyzed after fusion with sodium carbonate in the case of the Ata profile. Table VI contains the results of this analysis.

TABLE VI  
*Proximate analysis of clay*  
(Per cent air dry basis)  
*Ata profile*

Particulars	0 ft.-1 ft.	1 ft.- 2 ft. 4 in.	2 ft. 4 in.- 3 ft. 6 in.	3 ft. 6 in.- 4 ft. 8 in.	4 ft. 8 in.- 5 in.	5 ft.-6 ft.
SiO <sub>2</sub> . . . . .	44.03	43.85	44.26	45.10	44.90	44.89
Al <sub>2</sub> O <sub>3</sub> . . . . .	21.30	23.35	19.60	20.10	22.15	..
Fe <sub>2</sub> O <sub>3</sub> . . . . .	9.20	9.60	10.00	10.40	10.80	..
MgO . . . . .	2.46	2.46	2.17	2.57	3.17	3.77
K <sub>2</sub> O . . . . .	2.36	2.01	2.90	2.61	2.80	2.80
B. e. c. (m. e.) . . . . .	75.0	76.0	71.0	69.0	75.0	67.0
Free Fe <sub>2</sub> O <sub>3</sub> . . . . .	7.2	8.0	8.8	8.8	8.8	8.8
SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> . . . . .	3.50	3.18	3.83	3.80	3.44	..

The results of the clay analysis show the uniform composition of the clay fractions of the different layers of the profile. The silica content of the clays from the various depths is constant. Alumina content varies from 19.60 to 23.35 per cent. Iron content also does not differ much but has a distinct tendency of accumulation in the bottom layers. Similar tendency is also exhibited by the magnesia and potash contents. Of the total iron content of the clay major portion happens to be present as uncombined with the silicate complex. The base exchange capacity is high, the average figure being about 72 m.e. per cent. Within limits, the silica-alumina ratios are constant in the soil profile.

Altogether, it appears that in the soils reported in the present paper the pedogenic forces have not been such as to lead to distinct soil types. The main factors responsible for this state of affairs are the low rainfall and the flat topography. High clay and low coarse sand contents in the profile signify much soil disintegration presumably under the influence of subaqueous weathering of the parent material. There has, however, been very little translocation of the weathered material to lower depths. Even physical transfer of clay to lower depths has been absent; consequently there are no clear cut horizon differentiation. The soil and the clay composition in the profile accordingly present a uniform picture throughout.

The soils are, however, rich in exchange capacity being of montmorillonite character and this fact confers on them their unusual agricultural potentiality and the inexhaustible fertility. Having been formed from calcareous parent material and being of ferro-magnesian in origin the exchange complex is ordinarily well supplied with divalent cations specially calcium. There seems, however, some evidence of the complex getting rich in sodium specially in the bottom layers and this degradation is likely to affect adversely the physical characteristic of the clayey soils. It is in this respect that proper care in soil management is necessary if the existing fertility is to be preserved over a long period.

#### SUMMARY

Two representative soil profiles from district Jalaun in the plains of the Bundelkhand tract have been studied.

Chemical, mechanical and physico-chemical characters of the soil profiles have been discussed.

The profiles in general show very little translocation of the weathered material and hence the composition is more or less uniform throughout.

The analysis of the clay isolates shows that the average value of the  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratios is 3.55 and within limits this value is constant in the soil profile.

#### REFERENCES

- Agarwal, R. R. and Mukerji, P. (1946). Studies on Bundelkhand Soils of U. P. II. *Indian J. agric. Sci.* **16**, 483-491
- Drake—Brokeman, D. L. (1910). Jalaun ; A *Gazettee* (Govt. Press, U. P., Allahabad)
- Drosdoff, M. (1941). The Determination of Free Iron in Soil Colloids ; *Proc. Amer. Soc. Soil Sci.*, **6**, (1931-2)
- Mukerji, B. K. and Agarwal, R. R. (1943). Studies on Bundelkhand Soils, I; The Genetic types. *Indian J. agric. Sci.* **13**, 587-597
- Truog, E. et. al (1936). Procedure for Special Type of Mechanical and Mineralogical Soil Analysis. *Proc. Amer. Soc. Soil Sci.*, **1**, 101-112



# THE RELATIVE IMPORTANCE OF ORGANIC MANURES AND INORGANIC FERTILIZERS IN TROPICAL SOILS

By Dr S. Das, Indian Agricultural Research Institute, New Delhi

(Received for publication on 19 December 1947)

FROM a consideration of available evidence it would appear that the organic material decomposes progressively to humus under temperate conditions as a result of complicated biochemical and biological reactions in the soil; the three main effects of organic matter in the soil are due to (1) its content and availability of plant materials, principally compounds of N, P, K and Ca; (2) its influence on the activities of soil micro-organisms, and (3) the improvement of the physical condition of the soil. These observations obtained under temperate soil conditions have led agricultural scientists in India to accept them as a basis for further work. They have found that the effects of organic matter in tropical soils seem much more ephemeral than in temperate climates owing probably to the much quicker rate of decomposition and the smaller end-products in the soil. The average nitrogen and carbon contents of Indian soils are 0.05 per cent and 0.6 per cent respectively. Similar figures for European soils are 0.15 per cent N and 3 per cent organic C. European soils are thus 5 times richer in humus content and still the demand there is for organic matter. This explains the disappointing nature of fertilizer experiments on Indian soils. The needs of Indian soils are evident and the data from manurial experiments portray the requirements correctly. Cattle manure, green manure and other organic manures are valuable to soils, because they supply what is popularly known as humus which is so essential to maintain soil fertility. The cry for organic manures for Indian soils is even stronger and more imperative, because the disruption of organic matter is faster at high temperatures obtaining in India. The rate of destruction can be imagined when it is found that a soil at Coimbatore receiving cattle manure at 10 tons per acre per annum in two instalments continuously for 20 years, contains only 0.74 per cent of organic carbon as against 0.59 per cent in the unmanured soil.

The results in Table I indicate the status of C and N in soils of cool and warm climates under manurial treatments and otherwise.

TABLE I  
*Status of C and N in soils of cool and warm climates.*

Cool climates	C	N	C/N	Warm climates	C	N	C/N
Rothamsted— Broadbalk wheat— No manure since 1839	0.89	0.092	9.6	Gazira (Sudan) <sup>1</sup> South Africa— <sup>2</sup> Winter rainfall region	0.4 .. ..	0.03 .. ..	12.6 15

Percentage of C and N and C/N ratios in various surface soils (Cf. E. J. Russell—*Soil conditions and plant growth*. 7th ED. 1937)

TABLE I—*contd.*

Cool climates	C	N	C/N	Warm climates	C	N	C/N
F. Y. M. annually since 1843	2.91	0.263	11	Transvaal— <sup>3</sup> Black loam	1.87	0.13	14.4
Woburn, 1876	1.49	0.155	9.6	Siam— <sup>3</sup> Paddy soil	6.37	0.56	11.4
Woburn barley plots, 1932— No organic manure since 1876	0.92	0.095	9.7	Iowa— <sup>4</sup>	..	..	12.13
F. Y. M. annually since 1876	1.23	0.123	10.0	Average of Jenny's data <sup>5</sup>	..	..	9.2
Aber, North Wales— 6 grass <sup>2</sup>	3.22	0.35	9.2				
6 arable <sup>3</sup>	2.93	0.32	9.2				
50 English soils	..	..	10				
Poland <sup>6</sup>	..	..	10.4				

Percentages of C and N and C/N ratios in various surface soils (Cf. E. J. Russell—*Soil conditions and plant growth*, 7th Ed., 1937)

1 Average of 42 samples, 1st foot. A. F. Joseph

2 W. E. Isaac (1935). *Trans. Roy. Soc. S. Africa*, 23, 205

3 W. Mclean J. (1930). *Agric. Sci.*, 20, 348

4 P. E. Brown. *Iowa Agric. Exp. Sta. Bull.* 150, 1914

5 H. Jenny (1929). *Soil Sci.*, 27, 168

6 J. Kielpinski (1933). *Rocz. Nauk Roln. Poznan*, 30, 281

The rate of conservation of organic carbon by the continuous annual applications of organic manures to Pusa calcareous soils will be evident from the results in Table II.

TABLE II

*Permanent manurial plots, new series, Pusa soils examined in 1947*

Treatment per acre, annually since 1932	Average of 10 replications		
	C	N	C/N
A. No manure	0.28	0.034	8.2
B F. Y. M. at 8,000 lb.	0.37	0.045	8.1
C Rape cake at 40 lb. N	0.31	0.037	8.3

TABLE II—*contd.**Old permanent manurial plots, A and B series, Pusa soils examined in 1947*

Plot No.	Treatment per acre, annually since 1907	C	N	C/N	C	N	C/N
		(A series)			(B series)		
12	Green manure with purely cereal rotation	0.33	0.036	9.0	0.34	0.033	10.0
15	Effect of green manure and leguminous crop in rotation	0.34	0.041	8.3	0.38	0.039	9.8
16	As in 15 + Superphosphate at 80 lb $P_2O_5$	0.41	0.043	9.5	0.52	0.045	11.5
18	No manure . . . . .	0.37	0.029	13.0	0.34	0.030	11.3

A comparison of the results given in Tables I and II indicates that there is a considerable improvement in the status of nitrogen and carbon by the application of farmyard manure to the soils of temperate and cool climates, whereas very slight or hardly any improvement is observed in this direction in warm and tropical regions under similar applications of organic manures.

Keen [1946] records similar observations in the Middle East under the same tropical conditions as in India. He has mentioned [*loc. cit.*, p. 48] another interesting difference in Cyprus from temperate climate conditions in the residual (second-year) manurial effect of organic material. Comparing various organic manures with artificial fertilizers on the same N, P, K basis, the increases in yield were the same. But the residual effect of artificials was found more in the larger yield of the next unmanured crop of wheat, a result which is contrary to what is recorded in temperate climates. The explanation suggested is that in the low rainfall area of Cyprus, loss of artificials by leaching does not take place, and the high temperature and dryness of the soil in summer cause the organic matter to decompose more than the nitrogen artificial. In some other places the nitrogen in the organics did not produce an increased yield. In Nigeria the effect on yield was traced to the phosphate content of the manure. Thus Keen is indeed of opinion that a good case could be made out for the peasants' custom,—so generally condemned—of using dung as a fuel. As a very small proportion of its nitrogenous value is obtained by plants as indicated by the above instances and as the potash and phosphorus value of the dung will remain even in its ash, the heat of oxidation by burning the dung might better be utilised for domestic purposes than losing it uselessly in the soil.

These striking observations need be tested in the light of experience under Indian conditions which are similar to the tropical conditions of the Middle East.

From a note prepared by the Imperial Bureau of Soil Science on 'Additions of Organic Matter to Tropical Soils' it is evident that the general conclusion from experiments on green manuring in hot countries like Rhodesia, Uganda and South Russia is that its value depends on the N, P, K content of the manure, and not very much on the organic matter. Results with tea in Assam [Carpenter, 1938], Malaya and elsewhere [Mann, 1935] have shown conclusively that ammonium sulphate is at least as efficient as an equivalent of organic manure in maintaining both quantity and quality of yield. Comparison of the residual effects of green manures with fallow showed that the effects were only significant in the first year after ploughing in. Green manures brought about a marked increase in the carbon and nitrogen of the soil, but the effects were transitory. Within a year of being ploughed in the plant residues decomposed so effectively that hardly any trace was left of them. Therefore, the data did not lend much support to the contention of building up of soil fertility by means of green manuring. On the other hand, that bulky organic manure like green manuring enhances yield in irrigated rice is probably a universal finding all over India. This is well recognised by the cultivators, but still it cannot be adopted as a universal practice due to the absence of necessary facilities. Cultivators often collect green leaves from near by forests and apply them to the rice fields, where green manures cannot be conveniently grown. An application of 30 to 40 lb. of N in the form of green leaves can increase the yield of rice by 20 to 30 per cent. Heavy doses of 60 to 80 lb. of N have yielded even 100 per cent increase in certain centres.

Stewart [1947] considers the general picture emerging from experiments with bulky organic manures in India rather confused, as unlike concentrated artificial fertilizers which primarily supply plant food materials to the soil, bulky organic manures are complex and manifold in their action. They can simultaneously affect the chemical, physical and biological properties of the soil, and the experiments would be extremely complicated in design to accurately differentiate the individual changes brought about in the soil by the application of different organic manures. Because of the absence of analytical data for the materials used and the omission of any basis for the equivalent nutrients present in the different organic manures, it is difficult to assess the nutrient value of such materials under Indian conditions or explain apparently conflicting results from past experiments [Vaidyanathan, 1933; Rege, 1941; Sethi, 1943; and Panse, 1945].

Although conflicting results have been obtained from many experiments, the general conclusion arising from the bulk of evidence is that bulky organic manures play a very useful part in the maintenance of soil fertility and improvement of crop yields.

In an interesting series of trials on F.Y.M. at Dharwar where *jowar* was grown in rotation with cotton for several years in two sets of adjoining plots, the results obtained for seven years from 1932-33 to 1938-39 are given in Table III.

TABLE III

*Trials on F.Y.M. with jowar in rotation with cotton at Dharwar*

Treatment per acre	Response lb. per lb. N
Field manured every year at 25 lb. N . . . . .	30.0
Do. for jowar 25 . . . . .	17.2
Do. Do. 50 . . . . .	18.5
Do. Do. 100 . . . . .	15.7
Do. Do. 150 . . . . .	11.9

These results show how the continuous use of F.Y.M. can increase productivity of jowar. Even when F.Y.M. was applied in alternate years, increased crop yields were maintained from applications up to 150 lb. N per acre.

A remarkable result at Dharwar indicated that response of jowar to oil cakes was increased considerably when applied on a basal dressing of F. Y.M. The results for four trials are given in Table IV.

TABLE IV

*Response of jowar to oil cakes with and without F.Y.M. at Dharwar*

Treatment	Response lb. per lb. N			
	Castor	Safflower	Cotton	Karanj
Cake at 20 lb. N per acre— Without basal F. Y. M. . . . .	4.9	4.5	1.5	5.2
With basal F. Y. M. . . . .	15.4	15.9	14.0	14.4

The manurial value of farmyard and similar organic manures depends on the degree of decomposition in the season of application. Undecomposed material may utilise soil moisture to aid its decomposition and also soil nitrogen in the absence of available nitrogen from applied manures, as bacteria responsible for the decomposition of organic matter in the soil need nitrogen and may thus adversely affect the life of the plant at a critical period of its growth. Such factors are therefore often responsible for variations in response to organic manures applied at different times. For instance, in some areas the application of F.Y.M. in August gives better results with wheat than either June or October application due to the less availability of soil moisture in the latter. Under these conditions, an average response of 6.2 lb. per lb. N. was observed to cattle dung at various centres in C. P. and of 4.9 lb. per lb. N to F.Y.M. at Powerkhera.

Oil cakes are more efficient sources of N than F.Y.M. or cattle dung. *Til* (Sesamum) cake gave a response of 7.8 lb. of wheat per lb. N in 14 trials,—13 at Tharsa and one at Adhartal, *karanj* (*Pongamia glabra*) cake gave 6.9 lb. in five trials at Chindwara and castor cake 11.8 lb. in 9 trials,—7 at Labhandi and 2 at Tharsa. In 7 trials at Labhandi, night soils and poudrette applied at 30 lb. of N per acre gave responses of 16.0 and 11.3 lb. of wheat per lb. N respectively.

In one trial at Indore the results obtained are given in Table V.

TABLE V

*Effect of different organic manures and  $Am_2SO_4$  on wheat at Indore*

Treatment of N per acre	Yield of wheat lb. per acre			
	F. Y. M.	Compost	Night soil	$Am_2SO_4$
37 lb.	1422	1363	1345	1066
73 lb.	1526	1526	1807	1111
110 lb.	1532	1881	1837	1244

It is shown that at the high level of nitrogen applied, nitrogen from organic sources proved more effective than ammonium sulphate. Here, however, no account was taken of the contents of P and K contained in the organic manures, which might partly be responsible for producing higher yields with them.

It is rather difficult to assess the value of organic manures in single year or short-term experiments, and more detailed work of a long-term nature is needed. Norris [1923], while studying this aspect of the problem, discussed the results of 36 successive crops taken off the permanent manurial plots at Coimbatore that had been manured with cattle manure, or with ammonium sulphate, superphosphate and potassium sulphate singly and in different combinations. Comparing cattle manure with mineral manure, the average yields of crops manured separately with cattle manure and complete mineral manure expressed as per cent on 'No manure' are given in Table VI for two periods. The first covers 36 crops as dealt with by Norris [1923] and the second refers to the subsequent 20 crops dealt with by Viswanath [1931].

TABLE VI

*The results of permanent manurial plots at Coimbatore*

	No manure		Complete mineral manures		Cattle manure	
	Grain	Straw	Grain	Straw	Grain	Straw
From 1st to 36th crop—						
Cholam	100	100	292	191	295	192
Ragi	100	100	903	548	750	426
Wheat	100	100	246	230	171	191
From 37th to 56th crop—						
Cholam	100	100	336	165	384	202
Ragi	100	100	429	402	409	479
Ranivaragu	100	100	377	306	461	370
Wheat	100	100	237	201	356	290
Cambodia cotton kapas	100		133		191	

The effect of F.Y.M. on the first 36 crops was generally inferior to that of the complete mineral manure. The averages for the 37th to 56th crop were, with the exception of those for *ragi*, distinctly in favour of F.Y.M. It may be stated here that for *ragi* it was only in the case of crop No. 38 that the yield from the mineral manure plot was higher than that from the F.Y.M. plot. If this crop is left out, the average for the rest of the crops from the F.Y.M. plots are greater than those from the mineral manure plots.

Thus, artificial fertilisers are somewhat superior to F.Y.M. in the earlier years of their application, but in later years the F.Y.M. asserts itself in contributing to greater yields over artificial fertilizers. This conclusion is supported by the results of experiments at Rothamsted. Russell [1926] in his Hitchcock lectures in America, drew attention to this fact.

Viswanath [1930] has shown that organic manures assist the assimilation of chemical fertilizers in the soils tested by him.

TABLE VII

*Effect of Chemical fertilizers with and without organic manures*

*Pot cultures—Coimbatore*

<i>Treatments</i>		<i>Yield (relative merits taking green manure=1)</i>
Artificials . . . . .	No manure . . . . .	0.33
	P (superphosphate) . . . . .	0.50
	N (ammonium sulphate) . . . . .	0.70
	N+P ( $\text{Am}_2\text{SO}_4$ +Super) . . . . .	0.90
Artificials with organic manures	Green manure . . . . .	1.00
	G. M.+phosphate . . . . .	1.20
	G.M.+nitrogen . . . . .	1.33
	G.M.+N+P . . . . .	1.60

*Field experiments—Manganallur Experiment Station—Paddy*

	<i>lb. per acre</i>
Green leaf at 3,500 lb. per acre . . . . .	2,033
Green leaf at 3,500 lb. per acre + 1 cwt. $\text{Am}_2\text{SO}_4$ . . . . .	2,433
Ammonium sulphate 1 cwt. . . . .	2,073
Control . . . . .	1,653

*Palur Experiment Station—Sugarcane*

	<i>Per cent increase in yield over standard</i>
Cake N 50 lb. . . . .	Standard
Cake N 100 lb. . . . .	30.9
Cake N 80 lb.+mineral N 20 lb. . . . .	41.6
Cake N 60 lb.+mineral N 40 lb. . . . .	56.5
Cake N 40 lb.+mineral N 60 lb. . . . .	38.2
Cake N 20 lb.+mineral N 80 lb. . . . .	49.6
Cake N nil + mineral N 100 lb. . . . .	40.5

*Samalkot Experiment Station—Sugarcane*

Plot size 2.4 cents	Weight of cane per plot in lb.	Weight of cane per acre in lb.
Castor cake (107 lb. N) . . . . .	2,254	93,915
Castor cake + $\text{Am}_2\text{SO}_4$ (107 lb. N) . . . . .	2,499	104,166

For the soils tested above, neither chemical fertilizers nor organic manures by themselves are adequate. It is only by the combination of both that the best results are obtained. The addition of fertilizers increases the assimilation of the nutrients in F.Y.M. and *vice versa*.

Hendry [1928] carried out comparative experiments on the relative merits of organic manures and artificial fertilizers spread over a number of years. He applied different manures and fertilizers for five consecutive years and then measured their residual effects during another period of five years. The results are stated in Table VIII. The percentage increases due to residual effect are the averages of five yearly increases.

TABLE VIII  
*Hmawbi Experiment Station, Burma—Paddy*

Treatment per acre	Per cent increase over control (5 years)	Residual effect. Per cent increase over control during 5 years
Cattle manure at 30 lb. N . . . . .	+37.5	+21.8
Cattle manure at 50 lb. N . . . . .	+52.3	+34.5
Cattle manure at 70 lb. N . . . . .	+68.7	+37.8
Cotton cake at 50 lb. N . . . . .	+54.8	+29.2
Cattle manure at 30 lb. N + Super at 20 lb. $\text{P}_2\text{O}_5$ . . . . .	+43.6	+27.6
Cattle manure at 30 lb. N + Bonemeal at 20 lb. $\text{P}_2\text{O}_5$ . . . . .	+51.0	+31.8
Bonemeal at 20 lb. $\text{P}_2\text{O}_5$ . . . . .	+26.5	+9.5
Super at 20 lb. $\text{P}_2\text{O}_5$ . . . . .	+36.3	+15.3
$\text{K}_2\text{SO}_4$ at 20 lb. $\text{K}_2\text{O}$ . . . . .	+5.0	-6.6
$\text{NaNO}_3$ at 30 lb. N . . . . .	-17.0	-35.5
$\text{Am}_2\text{SO}_4$ at 30 lb. N + Super at 20 lb. $\text{P}_2\text{O}_5$ + $\text{K}_2\text{SO}_4$ at 20 lb. $\text{K}_2\text{O}$	+33.5	+17.5
$\text{Am}_2\text{SO}_4$ at 30 lb. N . . . . .	+32.5	-25.5

It is evident that while organic manures whose direct effects were in general equal or more than those of inorganic fertilizers, the residual effects of organic manures were in general more pronounced than the inorganic fertilizers, the exception being bonemeal among organics. Among inorganic fertilizers, super has some residual effects, as some of the soluble  $P_2O_5$  is fixed in the soil and part of the fixed  $P_2O_5$  is rendered available to the succeeding crop. No residual effect is however observed in the case of sodium nitrate or ammonium sulphate. The results of long-continued experiments at Rothamsted and Woburn in England point to similar results [*cf.* Russell, 1937] as stated in Table IX.

TABLE IX

*Figures for Rothamsted and Woburn Experiment Station*

Yield per acre

	Wheat average of 71 seasons	Barley average of 70 seasons	Mangolds average of 45 seasons
	Bushels	Bushels	Bushels
Rothamsted—			
14 tons F. Y. M.	34	46	18
Complete artificials	31	41	18
Woburn—			
7 tons F. Y. M.	20.5	27.7	..
Complete artificials	18.4	18.7	..

At Pusa, permanent manurial plots were laid out in 1908-09 with 16 treatments, including organic manures, green manures and inorganic fertilizers. These treatments were continued for 22 years upto 1929-30, when certain modifications in the

manurial treatments and crop rotations were made, under which these manurial experiments are being continued to date. There are now 18 treatments. The results of these two periods for some of the plots are stated in Table X and XI for comparison. There are two series of these experiments with the same manurial treatments, but having different crop rotations. During this period of 1908-09 to 1929-30 maize yields related to 22 years and there were 11 crops of *arhar* and oats. Manures were applied to maize every year, while the *rabi* crops showed only the residual effect, if any. These results were previously discussed by Menon and Bose [1937] and also by Parr and Sen [1947].

TABLE X \*

*Permanent Manurial Plots, Pusa**Average for 22 years from 1908-09 to 1929-30*

Yield in lb. per acre

Plot No.	Treatment per acre	A. Series			B. Series		
		Maize	Arhar	Oats	Maize	Arhar	Oats
1	No manure . . . . .	658	959	649	491	937	484
3	F. Y. M. to supply 20 lb. N. .	860	1,027	882	819	1,111	764
5	Rape cake to supply 20 lb. N as in F. Y. M. plot No. 3	939	929	656	785	869	576
10	$\text{Am}_2\text{SO}_4$ to supply N, $\text{K}_2\text{SO}_4$ to supply $\text{K}_2\text{O}$ and Super to supply $\text{P}_2\text{O}_5$ as in F. Y. M. plot No. 3	977	740	948	974	802	787
12	Green manure in cereal rotation .	804	384	622	749	461	649
16	G.M.+Super to supply $\text{P}_2\text{O}_5$ as in F. Y. M. plot No. 3	1,338	813	1,367	1,286	615	1,602

The composition of the F.Y.M. and rape cake applied varied from year to year and their contents of  $P_2O_5$  and  $K_2O$  were not constant. The average  $P_2O_5$  and  $K_2O$  in F.Y.M. analysed for 22 years are about 13 and 17 lb. respectively per acre for 20 lb. of N in F.Y.M. Similar figures for rape cake are about 8 lb. each of  $P_2O_5$  and  $K_2O$  per acre for every 20 lb. of N in rape cake. Except in the case of arhar, lower yields have been obtained for maize and oats with F.Y.M. and rape cake than with complete mineral manures. Green manure when combined with superphosphate has generally produced the best yields.

\* TABLE XI

*Permanent Manurial Experiments, Pusa**Average for 17 years from 1930-31 to 1946-47*

Yields in lb. per acre

Plot No.	Treatment per acre	A. Series					B. Series				
		Maize	Peas	Barley	Wheat	Arhar	Maize	Barley	Wheat	Arhar	Peas
1	No manure . . . . .	410	284	248	366	659	374	281	250	564	161
3	F. Y. M. at 8,000 lb. (=40 lb. N+26 lb. $P_2O_5$ +54 lb. $K_2O$ )	1,098	585	936	892	954	1,102	857	920	1,108	488
4	F. Y. M. at 4,000 lb.+Rape cake at 20 lb. N (=40 lb. N+21 lb. $P_2O_5$ +35 lb. $K_2O$ )	1,298	525	883	810	809	1,237	893	687	960	414
5	Rape cake at 40 lb. N (=40 lb. N+15 lb. $P_2O_5$ +15 lb. $K_2O$ )	1,007	307	728	568	767	888	596	441	706	274
10	$Am_2SO_4$ at 40 lb. N+Super at 80 lb. $P_2O_5$ + $K_2SO_4$ at 50 lb. $K_2O$	769	493	1,069	765	858	682	1,160	687	1,049	422
15	Effect of green manure and leguminous crop in rotation	597	247	745	599	482	531	795	553	500	197
16	As in 15 with additional application of super at 80 lb. $P_2O_5$	797	590	2,063	1,504	878	696	1,707	1,295	1,057	705

From the average composition of F.Y.M. and rape cake the values for  $P_2O_5$  and  $K_2O$  have been computed for comparison with the complete mineral manure plot. Except for slightly more of  $K_2O$  in the F.Y.M. plot No. 3, in all other cases of F.Y.M. and rape cake plots the contents of  $P_2O_5$  and  $K_2O$  are lower than those in the complete manure plot. Notwithstanding this, except with barley and in the rape cake plot the crop performance in the former is generally much better than in the latter which cannot be justified on the NPK basis alone. Green manuring combined with superphosphate has produced excellent yields, especially in the case of barley, wheat and peas.

These results show that even on the NPK basis, F.Y.M. alone or combined with rape cake has generally given better outturns than the complete mineral manures. This is rather striking and may be attributed to the presence of organic matter in the former.

Similar results are noticed in the New Manurial Series of the Permanent Manurial Plots at Pusa laid out in 1932 with ten treatments of ten replications each in randomised blocks. There is a four year rotation with maize as the *kharif* crop every summer followed by oats, peas, wheat and gram year after year as the *rabi* crop. As in the interval of 1932 to 1947, there are only about four *rabi* crops of each variety, only the yield of maize grown every year is considered in Table XII.

TABLE XII

*Permanent Manurial Experiments, Pusa*  
*New Manurial Series*

*Average for 15 years from 1932-33 to 1946-47*

Yield of maize in lb. per acre

No manure	F. Y. M. at 8000 lb.=40 lb. N+23 lb. $P_2O_5$ +56 lb. $K_2O$	Rape cake at 40 lb. N per acre=40 lb. N+15 lb. $P_2O_5$ +15 lb. $K_2O$	$Am_2SO_4$ at 40 lb. N+ Superphosphate at 80 lb. $P_2O_5$ + $K_2SO_4$ at 50 lb. $K_2O$ per acre
207	421	547	395

Critical difference at 1 per cent=89.9

Critical difference at 5 per cent=67.7

Here it is evident that the F.Y.M. plot and particularly the rape cake plot have given higher yields of maize than the complete mineral manures. Rape cake is more quick-acting than F.Y.M. which decomposes rather slowly in the soil, and has therefore produced much better results than the F.Y.M. On the other hand, F.Y.M. and rape cake plots both contain much less  $P_2O_5$  than the complete manure plot, while F.Y.M. plot contains a little more of  $K_2O$  and the rape cake plot much less of  $K_2O$  than the complete manure plot. Notwithstanding this deficiency, the organic manure plots have produced better yields than what can be expected on NPK basis alone. The conclusion therefore emerges that this higher yield should be attributed to the beneficial action due to the presence of organic matter in them. With the introduction of organic matter, great biochemical and biological reactions set in the soil. The increased microbiological activity not only makes the N and P of the added materials available, but also increases the rate at which the soil N and soil P become available, thus raising the general status of soil fertility. The soil is able to supply to the growing crops not only what is put in the soil in the form of manures, but also a considerable portion of its reserve N, P and K which were formerly not available. Active soil organisms determined by insertion of slides and fixing the micro-organisms on them in the field indicate that good growth of crop is associated with a large number of active organisms. In the adjoining plots of poor growth the number of active organisms is very much low.

The yield data of A and B series of permanent manurial plots at Pusa have shown that the green manure combined with superphosphate generally produces favourable results compared with other treatments involving complete mineral manures or organic manures like F.Y.M. and rape cake. Das [1947, unpublished data] reports results from similar experiments in Table XIII.

TABLE XIII

*Field Experiments at Pusa*

*Manurial value of Superphosphate and green manure (sunn hemp) in Pusa calcareous soils*

*Yield of oats grain in lb. per 1/30 acre plot*

Green manure (sunn hemp) and superploughed in the monsoon: the land kept fallow in *kharif* and a *rabi* crop of oats taken

Plot No.	Treatment	1923-24	1924-25*	1925-26	1926-27	1927-28	1928-29	1929-30	Mean yield in lb. per plot	Per cent increase over control
1	Control . . .	9.73	34.40	14.87	13.87		29.77	14.37	16.52	..
2	Green manure .	17.43	63.13	29.27	26.17		26.17	33.87	26.58	60.90
3	Superphosphate .	20.27	51.33	26.70	17.43		17.43	11.30	18.63	12.77
4	G. M.+Superphosphate	22.07	71.33	41.07	30.80	No experiment	33.87	40.53	33.57	103.21
	Standard error .	3.93	..	..	..		..	..	..	..
	Critical difference at 1 per cent	12.01	..	..	..		..	..	..	..
	Critical difference at 5 per cent	8.56	..	..	..		..	..	..	..

\* The results of the year 1924-25 were omitted for the purpose of the combined statistical analysis on account of exceptionally high yields, although the standard error and critical differences altered but little from those obtained by including these results.

The effect of green manuring in releasing added, but fixed  $P_2O_5$  to the crop and thereby increasing the yield is evident.

One general conclusion that emerges from these experiments at Pusa and elsewhere is that if F.Y.M. or any other organic manure is applied well in advance to decompose almost completely at the time of sowing, besides the NPK value of organic manures, there are other beneficial effects accruing from their presence in the soil.

Hutchinson [1923] has shown by field experiments that the application of previously fermented green manure, sunn hemp (*Crotalaria juncea*) with superphosphate gives greater crop returns in calcareous Pusa soils than the same ploughed in along with super. The green manure combined with super, on the other hand, yields better crops than super alone.

TABLE XIV

*The effect of Superphosphate alone and with green and fermented sunn hemp at Pusa*

Plot No.	Treatment.	Kharif			Total kharif	Difference from control	Rabi				Total	Difference from control
		1918	1919	1920			1917-18	1918-19	1919-20	1920-21		
		Green maize lb. per acre					Oat grain lb. per acre					
26.	Super only (3 cwt.) .	20,196	15,810	11,170	47,176	+1,512	1,185	554	649	585	2,973	+86
32.	Super+green sunn .	20,960	13,387	11,416	45,763	+99	2,080	764	762	663	4,269	+1,382
22.	Super and fermented sunn, 3 to 1 concentration	21,748	15,441	10,677	47,866	+2,202	1,977	1,131	907	577	4,592	+1,705
30.	Super and fermented sunn, 6 to 1 concentration	29,501	19,301	16,837	65,639	+35,036	2,643	1,564	934	910	6,051	+3,106
24.	Control for No. 30 .	14,176	9,199	7,228	30,603	..	1,049	636	737	523	2,945	..
27. 31.	} Controls average .	20,504	12,471	12,689	45,664	..	1,036	631	609	561	2,837	..

Although superphosphate alone has but little effect on the oat crop, the increase due to its action in conjunction with organic residues is considerable. Further, the latter increase rises in proportion to the amount of organic matter added to the soil, and in this combination, in which the superphosphate appears to supply a limiting factor otherwise in defect in Pusa soil, the great value of the concentration 6 to 1 dose of fermented sann-hemp becomes obvious.

It is conceivable that organic phosphorus complexes are formed by the combined action of phosphatic fertilizers with humic or organic acids resulting from the decaying organic matter in the soil, whether present *in situ* or added as organic manures. And it is quite probable that such organic phosphates are significantly related to the crop yield resulting from the combined application of phosphatic fertilizers and organic matter.

Das [1945], while indicating the possibility of this effect, has recently shown that such organic phosphates are formed on composting green manure with phosphatic fertilizers and can be isolated for studies in water-culture experiments as against inorganic phosphates ( $K_2HPO_4$ ) present in Knopp's nutrient solution. These organic phosphates are soluble in water, neutral in reaction, and possess colloidal properties. They remain in a highly dispersed state in the soil and have been shown to be more available to plants by water-culture experiments than the inorganic phosphates of phosphatic fertilizers used in ordinary farm practice, which are generally insoluble or eventually become so on reacting with soil bases. The data in Table XV explain this effect.

TABLE XV

*The growth of ragi seedlings in nutrient solutions having inorganic and organic phosphates in them separately*

Weights in mg. of 12 ragi seedlings

No.	Nature of nutrient solutions	Initial	Final (after 5 weeks)	Difference	Per cent increase over control
1	Knopp's solution (control)	4.4	10.2	5.8	—
2	Knopp's solution devoid of $P_2O_5$ +organic phosphates isolated from the compost of lucerne+mono-calcium phosphate	4.1	15.2	11.1	91.4
	Duplicate+ do.	4.3	15.5	11.2	93.1
3	do. +Organic phosphates isolated from the compost of lucerne+di-calcium phosphate	4.2	14.8	10.6	82.8
4	do. +Organic phosphates isolated from the compost of lucerne alone	4.3	14.5	10.2	76.0

With regard to the efficacy of organic phosphates derived from different sources it is found that the compost of lucerne and monocalcium phosphate is the best, next comes in order the compost of lucerne and dicalcium phosphate, and the last is the compost of lucerne alone. In actual field practice already reported it has been observed that the compost of green manure and superphosphate or both ploughed in together always give better crop yields than either super or green manure applied alone.

#### DISCUSSION

The work of Spencer and Stewart [1934] lends support to the contention as to the better efficacy of organic phosphates in soil. They showed that phosphates in the organic form of the type formula  $R(OH)_x(OPO_3 M_x)_z$  escapes, to a marked degree, the fixation in soil which normally occurs to the phosphates applied in inorganic forms. They experimented with organic phosphates of the above type prepared in the laboratory, such as, calcium mono-orthophosphate of glycerol  $C_3H_5(OH)_2 \cdot OPO_3 Ca$  and potassium sorbityl diorthophosphate  $C_6H_8(OH)_4 \cdot (OPO_3 K)_2$ . A highly calcareous soil did permit little phosphorus in the filtrate when a solution of pure monocalcium phosphate was allowed to percolate through it, whereas, under the same conditions, much phosphorus passed through the soil when the above organic phosphates were used for percolation. Thus the permeation of phosphates in the organic form into deeper soil layers in the close environs of plant roots is assured. This is also supported by the theory put forward by Ramann [1911] and Comber [1922] which suggests a distinct possibility of plant roots absorbing phosphates direct, probably through contact with the soil colloids and also by the hypothesis of Greenhill [1930], according to which 'solid phase' feeding of phosphoric acid by the roots of crops is probable.

The importance of the phosphate manuring of legumes for increasing the yield and feeding quality of the leguminous crop as such and also for improving general soil fertility has been ably demonstrated by Parr and Bose [1944 and 1945]. It is also quite probable that the decaying organic matter combines not only with the phosphates of the phosphatic fertilizers applied to form organic phosphates as stated above, but can also easily react with the reserve insoluble phosphates in the soil to form organic phosphates which become available to the growing crops as demonstrated by Das [1945]. This additional advantage of reserve soil phosphates being available to plants due to their reaction with the decaying organic matter besides the latter's NPK nutrients, is absent in the case of complete mineral fertilizers which supply only the NPK contained in them. The majority of Indian soils being deficient in available phosphates, the above phenomenon accounts, in a large measure, for the higher crop-returns from the applications of organic manures than complete mineral manures, although both of them may be applied on the same NPK basis.

As a matter of fact, it has already been observed in the permanent manurial experiments with Pusa soils that F.Y.M. and rape cake having even lower contents of  $P_2O_5$  than the treatment with complete mineral manures gave higher crop yields than the latter. This can be explained by the fact that reserve soil phosphates

react with the decaying organic matter of F.Y.M. and rape cake, forming organic phosphates which become available to the growing crops and thus supplement the lesser amounts of  $P_2O_5$  present in the organic manures applied. It is quite possible that the reserve N and K of the soil also which were not formerly available might be rendered available to the plants like the reserve phosphates due to the application of organic matter to the soil. It has already been pointed out that the application of organic matter improves the microbiological activity of the soil. This in its train may bring about the above reactions resulting in the availability of the reserve N, P and K in the soil. Thus, the soil which receives organic manures is able to supply not only what is put in, but a considerable portion of its reserve of N, P and K which were formerly not available. This additional advantage accruing from the presence of sufficient organic matter in the soil, either present *in situ* or applied as organic manures, is reflected in the higher crop returns, when compared with the inorganic fertilizers applied even on the same NPK basis.

#### SUMMARY AND CONCLUSIONS

Many experiments have been reported above to show that neither chemical fertilizers nor organic manures by themselves are adequate. It is only by the combination of both that the best results are usually obtained. The greatest returns are in general obtained with nitrogenous fertilizers, although the action of phosphates is considerable. The response to the application of potassic fertilizers is not appreciable. The addition of fertilizers increases the assimilation of nutrients in the organic manures such as, F.Y.M., oil cakes and green manures, etc. and *vice versa*.

Although it is true that the continuous application of heavy organic manures even for a number of years does not ultimately much raise the C and N status of the soil, their application does play an important role in the maintenance of soil fertility and the improvement of crop yields in tropical soils. For, during the growing period of crops, the organic matter functions in stimulating the microbial activity of the soil which brings about in its train other beneficial effects in the form of rendering available the reserve N, P and K in the soil which were formerly not available. By the time the growing crops reach the stage of harvest, the beneficial action of organic matter almost comes to an end at the high prevailing temperature of the tropics, which quickly decomposes the organic manures, even though heavily applied. The beneficial effect thus lasts usually for the growing period of crops. Hence there is the great necessity of annual applications of organic manures to maintain the soil fertility at a high level and also to conserve all available sources of organic manures in the country. While stressing the importance of organic manures for tropical soils, the value of mineral supplements is not minimised.

The general evidence to date indicates that organic manures and inorganic fertilizers are both useful and they should be regarded as complementary in their effects. Experience in India and elsewhere has demonstrated both the value of organic manures and the inadequacy of the amounts available for general agriculture. Even if no cowdung were used as fuel and if all available organic and other

waste materials likely to be of manurial value were conserved and returned to the land, the supply would still fall far short of demands to improve and maintain soil fertility at a high level of crop performance. It is therefore reasonable to take all possible steps to return to the land all organic waste materials of value and to provide for supplementing such materials with mineral and other fertilizers as are likely to play an important part in maintaining and improving soil fertility.

## ACKNOWLEDGEMENT

The author's thanks are due to Dr. J. N. Mukherjee, Director of this Institute for his helpful criticism during the preparation of this article.

## REFERENCES

- Carpenter, P. H., (1938). The Application of Science to Modern Tea Culture. *Emp. J. Expt. Agric.* **6**, (1-10)
- Comber, N. M., (1922). The availability of mineral plant food. A modification of the present hypothesis *J. Agric. Sci.* **12**, 363
- Das, S., (1945). The combined action of organic matter and phosphatic fertilizers in soils *Ind. J. Agric. Sci.* **15**, 42
- Das, S., (1947). Unpublished data
- Greenhill, A. W., (1930). The availability of phosphatic fertilizers as shown by an examination of soil solution and of plant growth. *J. Agric. Sci.* **20**, 559
- Hendry, D., (1928). Manuring of paddy in lower Burma. *Agric. J. India*, **23**, 357
- Hutchinson, C. M., (1923). The value of fermented green manures as tested at Pusa by the prevalent plot method. *Agric. J. India*, **18**, 219
- Keen, B. A., (1946). *The Agricultural Development of the Middle East*
- Mann, H. H., (1935). Tea soils. *Imp. Bur. Soil. Sci. Tech. Com.* **32**
- Menon, T. V. G. and Bose, S. S., (1937). A statistical study of the yields of the permanent manurials, Pusa. *Ind. J. Agric. Sci.* **7**, 193
- Norris, R. V., (1923). Note on the permanent manurial plots at Coimbatore. *Mem. Dept. Agr. India, Chem. Ser.* **6**
- Panse, V. G., (1945). Manuring of cotton in India. *Bulletin of Ind. Cent. Cott. Comm.*
- Parr, C. H. and Sen, S., (1947). Phosphate manuring of legumes in relation to green manuring. *Ind. Farm.* (In the press)
- Parr, C. H. and Bose, R. D., (1944 and 1945). Phosphate manuring of legumes. *Ind. Farm.* **5**, **4** and **6**, **5**
- Ramann, E., (1911). *Bodenkunde*, Berlin
- Rege, R. D., (1941). Fertilizer experiments on sugarcane in India 1932-39, I. C. A. R. Miscellaneous Bulletin No. **41**
- Russell, E. J., (1926). Plant Nutrition and Crop Production. University of California Press
- Russell, E. J., (1937). *Soil Conditions and Plant Growth*. 7th Ed.
- Sethi, R. L., (1943). Manuring of Paddy. I. C. A. R. Miscellaneous Bulletin No. **38**
- Spencer, V. E. and Stewart, R., (1934). Phosphate studies. I. Soil penetration of some organic and inorganic phosphates. *Soil. Sci.* **38**, 65
- Stewart, A. B., (1947). *Report on soil fertility investigations in India with special reference to manuring*. Army Press, Delhi
- Vaidyanathan, M., (1933). Analysis of manurial experiments in India. I-III. I. C. A. R.
- Viswanath, B., (1930). *Madras Agric. J.* **18**, 421
- Viswanath, B., (1931). Food requirements of crops with reference to South Indian soils. *Ind. J. Agric. Sci.* **1**, **4**



## DEVELOPMENT OF COTTON SEED AND LINT DURING THE SECOND PHASE OF BOLL MATURATION

By S. M. NAWAZ, Technological Assistant, Cotton Research Laboratory, Lyallpur

(Received for publication on 31 August 1946)

(With eight text-figures)

WITH the initiation of the reproductive phase in the cotton plant, fruiting parts become the centre of great metabolic activity and very rapid physiochemical changes take place in the developing boll. The development of the fibre begins before fertilization by the elongation of the epidermal cells of the ovules. Similarly the ovules also begin increasing in size and the development of their internal tissues is initiated before fertilization has taken place. A very high percentage of the flowers is, however, subsequently shed as young bolls. The maturation period of bolls, apart from being a varietal character, is greatly influenced by the environment, and during practically the whole of this period the lint hairs are growing and developing.

Balls [1915] was the first to study the development of the cotton boll of an Egyptian variety of cotton (Strain No. 77) grown at Giza. He observed that the developing boll attained its full size in the first half of its maturation period. The seeds grew rapidly up to the 18th day after flowering. He also found that the development of the lint hairs took place in two distinct phases. The first half of the boll maturation period, being occupied by the lengthening of the primary wall of the hair, is followed, in the second half, by cellulose deposition in the form of daily concentric rings on the inner surface of the cell wall. The cotton fibre was, thus, shown to increase only in length during the first half, and only in strength and maturity during the second half of the boll maturation period.

A few other workers have also dealt with this aspect of the problem. Hock, Ramsay and Harris [1941], during their study on the microscopic structure of the cotton fibre observed that the percentage of cellulose in a series of cotton samples of different ages, increased rapidly with the age of the boll till about the 35th day after flowering. This observation was made on two varieties of *hirsutum* cotton, namely Missdel-7 and Mexican Big Boll, grown at the Delta Experiments Station, Stonewill. Iyengar [1943], while studying the variation in fibre properties of a number of pure strains evolved from Cambodia cotton *G. hirsutum*, grown in different places in Madras, found that the rate of wall thickening was more or less constant at Coimbatore, while it decreased appreciably with the age of the boll at Srivilliputhur.

These findings have thrown open a very wide field of research into the development of cotton fibre, but so far as the writer is aware, growth changes in various seed and lint characteristics, during the second phase of boll maturation have not been studied in great details so far. In order, therefore, to fill up this gap in the

present knowledge, studies were undertaken in 1942 at the Cotton Research Station, Mirpurkhas—Sind and the growth changes in seed weight, lint index, fibre weight per unit length and maturity counts were studied in detail.

#### MATERIAL AND METHOD

Two strains of *hirsutum* cotton namely M-4 and Sind Sudhar (S.S.), extensively grown in Sind at present, were studied for three consecutive seasons, 1942, 1943 and 1944. In a 'bulk plot' of each variety some 4,000 flowers were tagged on one day during profuse flowering. On the 18th day after flowering 20 to 30 developing bolls were collected at random. These were gently cut open and the locks were fixed immediately in the following solution.

Picric acid . . . . .	1 gm.
70 per cent alcohol . . . . .	75 c.c.
Formalin . . . . .	25 c.c.
Glacial acetic acid . . . . .	5 c.c.

The material was kept in this solution for 48 hours and was then thoroughly washed with methylated spirit. It was then dried in the sun. Such random samples of bolls were regularly drawn and fixed as above on alternate days till the 36th day after flowering.

The details of sampling dates for different seasons and varieties are set out in Table I.

TABLE I  
*Sampling dates*

Seasons	1942		1943		1944	
	M-4	S.S.	M-4	S.S.	M-4	S.S.
Date of tagging of flowers . .	1-8-42	29-8-42	10-8-43	31-8-43	25-8-44	11-9-44
Date of first sampling . . . .	20-8-42	15-9-42	27-8-43	17-9-43	11-9-44	28-9-44
Date of last sampling (10th)	5-9-42	3-10-42	14-9-43	5-10-43	29-9-44	16-10-44

The seed-cotton obtained from each sample was thoroughly mixed and a random sample of 200 seeds with lint on, was taken out for making various determinations. The lint was later carefully separated from seeds by hand.

The following features were studied for each sample :

1. Seed weight per 100 seeds.
2. Lint Index (weight of lint on 100 seeds).
3. Ginning percentage.
4. Mean fibre length in inches.
5. Mean fibre weight per unit length (whole fibre).
6. Mean fibre weight per unit length of middle section.
7. Maturity counts.

The mean fibre length was determined by means of the Attachment to the Stapling Apparatus designed by Ahmad and Nanjundyya [1938]. The mean fibre weight was found by weighing five tufts, each of about 400 whole fibres, on the torsion balance, and then expressing the mean result as weight per unit length. The mean fibre weight per unit length of middle section was determined by cutting a known length of the middle section by means of the Stapling Apparatus [1936]. After counting the number of fibres in that section, the tuft was weighed on the torsion balance. The unit fibre weight, calculated from the weight of the bunch and the number of fibres it contained, was converted into mean fibre weight per unit length. The maturity of the fibres was determined with the help of Gulati and Ahmad's [1936] maturity slide.

### EXPERIMENTAL RESULTS

The experimental data are given in Tables XVII to XXIII in the Appendix. It will be convenient to discuss these under two sub heads, namely (a) Growth of seed and lint, and (b) developmental changes in fibre properties.

#### (a) *Growth of seed and lint*

The actual data pertaining to seed weight, lint index and ginning percentage are given in Tables XVII to XIX in the Appendix.

In order to remove the discrepancies, introduced by uncontrollable factors, in the development of seed and lint, growth curves of the logistic type were fitted to the observed values of seed weight and lint index for each cotton and for each season separately. The method of fitting the curves is given below in detail [Mills, 1938].

The equation to a logistic curve is  $1/y = a + bc^x$ , where  $y$  is the property under discussion and  $a$ ,  $b$  and  $c$  are the constants. Reciprocals of  $y$  are determined and multiplied by suitable numbers to get rid of the decimals. The chronologically arranged data are then divided into three equal groups,  $n$  being the number of observations in each group, and  $S_1$ ,  $S_2$  and  $S_3$  the total of the three groups. Then

$$d_1 = S_2 - S_1 \text{ and } d_2 = S_3 - S_2 \text{ and } C^3 = d_2/d_1$$

$$b = \frac{d_1 (c-1)}{(C^3-1)^2} ; \text{ and } a = 1/n \left[ S_1 - \frac{d_1}{(c^n-1)} \right]$$

Where  $x$  is the number of intervals in the growth period, each interval in the present case is of two days.

## ILLUSTRATION

Period	Y= Lint index	1/y × 100,000
20 . . . . .	1.30	76923
22 . . . . .	2.16	46296
24 . . . . .	2.63	38023
26 . . . . .	2.73	36630
28 . . . . .	3.26	30675
30 . . . . .	3.62	27624
32 . . . . .	3.92	25510
34 . . . . .	3.91	25575
36 . . . . .	4.07	24570

$$d_1 = -66313 = S_2 - S_1 \quad C^3 = \frac{-19274}{-66313} = + 0.29065$$

$$d_2 = -19274 = S_3 - S_2 \quad C = 0.66220$$

$$b = \frac{-66313 \times -3378}{(-0.70935)^2}$$

$$= 22400.53/0.503177$$

$$= 44518$$

$$a = \frac{1}{3} (161242 - \frac{-66313}{-0.70935})$$

$$= 22586$$

To obtain the calculated values of y, the equation was worked out for each observation of the above illustration. The observed as well as the calculated values are given below :

Period in days	Observed	Calculated
20 . . . . .	1.30	1.490
22 . . . . .	2.16	1.921
24 . . . . .	2.63	2.375
26 . . . . .	2.73	2.815
28 . . . . .	3.26	3.211
30 . . . . .	3.62	3.539
32 . . . . .	3.92	3.796
34 . . . . .	3.91	3.989
36 . . . . .	4.07	4.127

In order to see if there were varietal difference in the mode of development of seed and lint of both the cottons, the mean values of all seasons for each variety were worked out and curves were fitted to the data as shown in Figs. 1 and 2.

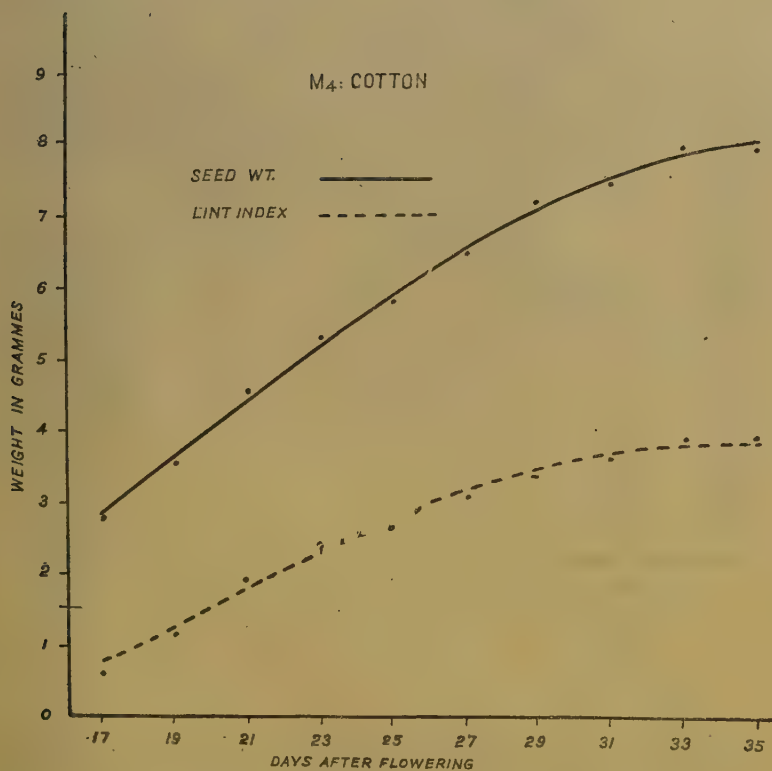


FIG. 1. Growth of seed weight and lint index (observed and calculated)

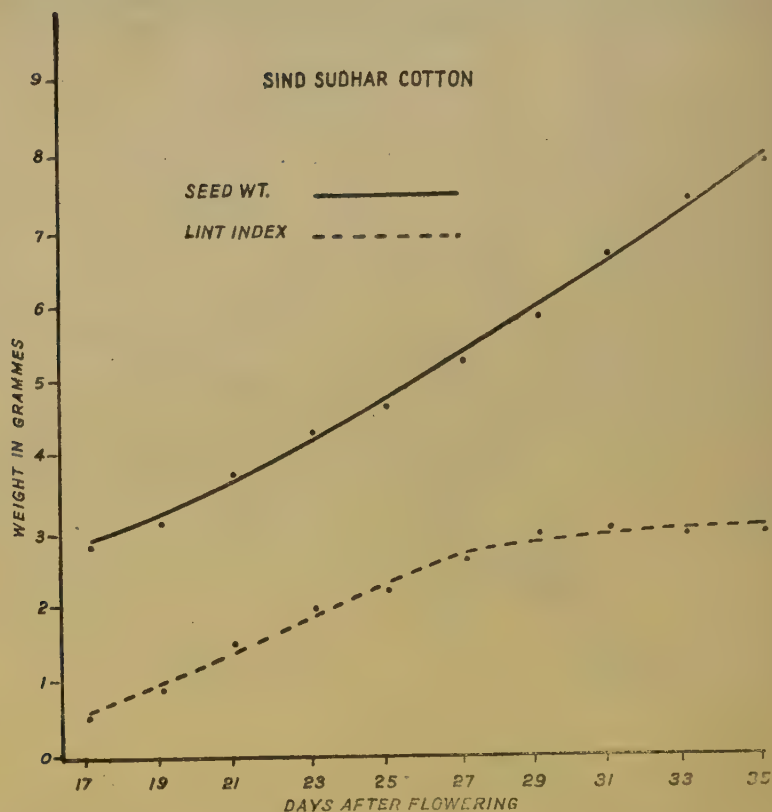


FIG. 2. Growth of seed weight and lint index (observed and calculated)

It is interesting to note from these figures that the curves for seed weight and lint index manifest a divergence from each other with the age of the boll. In the case of Sind Sudhar, the two curves run parallel for about a week, and then divert from each other. In the case of M-4, on the other hand, there is a steady increase in the angle of two curves from the very beginning of second phase of boll development. It will, however, be noticed that in the case of M-4, the curve of the seed weight showed a depression in its angular trend a few days before the boll finished its life cycle, showing thereby the lag in the rate of development of M-4 as compared to Sind Sudhar.

In view of such differences in the rate of growth of lint and seed in these two cottons, it was felt necessary to study the differential changes in seed weight and lint index by working out the relative rate of growth of each property with the help of the following formula.

$$\begin{aligned}\text{Relative rate of growth} &= \frac{1}{w} \frac{dw}{dt} = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1} \\ &= \frac{1}{2} (\log_e w_2 - \log_e w_1)\end{aligned}$$

Where  $W_1$  and  $W_2$  are the weights of seed or lint on two successive days in the age of the boll. The values of relative rate of change of lint index and seed weight and their ratios are given in Table II and Table III for each cotton separately.

TABLE II

*M-4 : Relative rate of growth of seed weight and lint index and their ratios*

Age of bolls in days	1942			1934			1944		
	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio
18	..	..	..	·1850	·1061	1·743	·2023	·0955	2·118
20	·1268	·0757	1·674	·1515	·0927	1·634	·1676	·0867	1·933
22	·1074	·0718	1·496	·1158	·0782	1·481	·1330	·0772	1·722
24	·0848	·0654	1·297	·0824	·0644	1·281	·0940	·0669	1·405
26	·0648	·0609	1·063	·0554	·0515	1·076	·0668	·0564	1·184
28	·0489	·0550	0·890	·0354	·0404	0·878	·0440	·0467	0·942
30	·0354	·0502	0·706	·0218	·0308	0·705	·0278	·0383	0·725
32	·0240	·0444	0·549	·0132	·0230	0·575	·0157	·0314	0·500
34	·0160	·0392	0·410	·0079	·0161	0·402	·0092	·0243	0·379

TABLE III

*Sind Sudhar : Relative rate of growth of seed weight and lint index and their ratios*

Age of bolls in days	1942			1943			1944		
	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio	Lint index	Seed weight	Ratio
18	·2329	·0656	3·546	·1960	·0645	3·039	·2526	·0644	3·922
20	·1956	·0648	3·016	·1669	·0648	2·577	·1534	·0595	2·578
22	·1563	·0634	2·466	·1373	·0607	2·262	·1197	·0563	2·126
24	·1168	·0626	1·866	·1056	·0601	1·757	·0903	·0526	1·717
26	·0806	·0603	1·337	·0770	·0581	1·326	·0639	·0476	1·342
28	·0505	·0588	0·860	·0516	·0552	0·935	·0418	·0442	0·945
30	·0310	·0570	0·455	·0341	·0533	0·639	·0276	·0392	0·704
32	·0192	·0554	0·345	·0229	·0501	0·447	·0136	·0349	0·390
34	·0100	·0533	0·188	·0135	·0478	0·282	·0106	·0307	0·345

The relative rate of growth of both the characters for each variety is shown in Figs. 3 and 4. An examination of Tables II and III and the relevant graphs would show that the relative rate of growth of lint index for both the varieties was markedly higher than that of the seed weight in the beginning of the second phase of boll maturation. With the advance in the age of the boll, both the growth rates manifested a gradual fall which was much steeper in the case of lint index than of the seed weight. This resulted in narrowing down the initial differences between the two rates and ultimately on or about the 27th day after flowering both the curves converged to a point. The relative rate of growth of lint index and seed weight became almost similar on that date, and thereafter reversed their positions with increasing difference till the day of boll opening. This phenomenon was manifested in all the three seasons for both the cottons at about the same age of the boll.

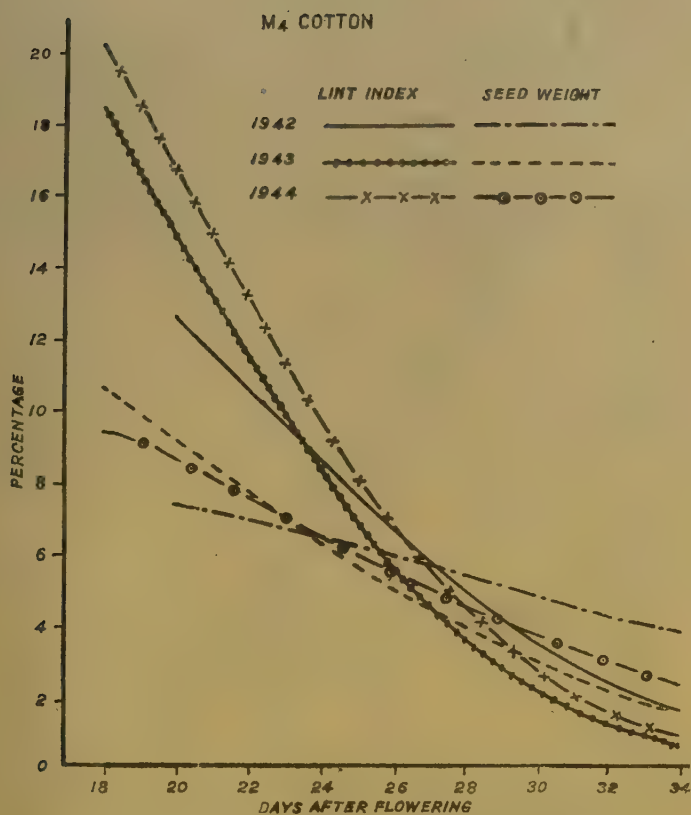


FIG. 3.—Relative rate of growth of lint index and seed weight

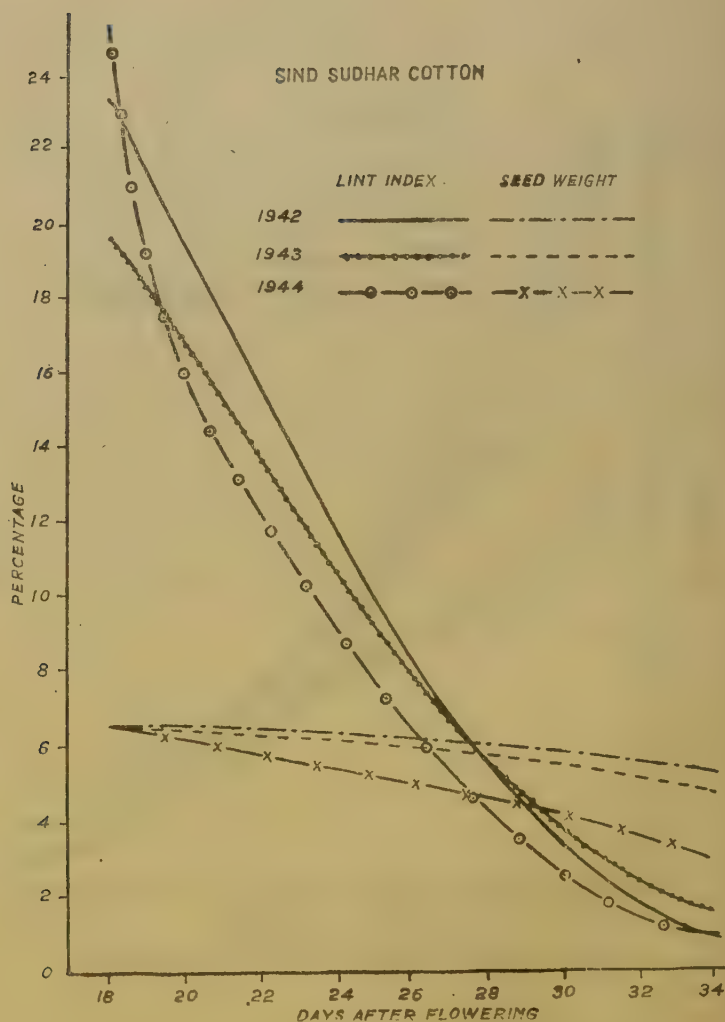


Fig. 4.—Relative rate of growth of lint index and seed weight

It is, however, interesting that the angle of convergence of curves for seed weight and lint index is bigger in the case of Sind Sudhar than that of M-4. A reference to Tables II and III would reveal that Sind Sudhar exhibited invariably a lower relative rate of growth of seed weight than M-4 in the beginning of the second phase of boll maturation, but with the advance in age this difference narrowed down systematically till about the 27th day, when it became zero, after which Sind Sudhar grew in seed weight comparatively more than M-4. In the case of lint index, Sind Sudhar had usually a higher rate of growth than M-4 all through the period of development, barring a few exceptions just at the tail end of its growing period. This explains the difference in the angle of convergence of curves in both the varieties.

### *Ginning percentage*

After fitting the growth curves the ginning percentages were worked out from the calculated values of seed weight and lint index. These values are given in Table IV.

TABLE IV

### *Ginning percentage*

Age of bolls in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17		26.0	21.4	17.2	19.7	20.0
19	28.6	29.2	25.1	22.4	24.2	23.9
21	30.6	31.7	28.3	27.3	28.2	27.5
23	32.2	33.4	30.5	31.1	31.4	30.1
25	33.6	34.2	31.8	33.5	33.4	31.7
27	33.2	34.4	32.2	34.4	34.2	32.4
29	33.0	34.2	32.1	34.1	34.1	32.3
31	32.4	33.6	31.6	32.9	33.2	31.9
33	31.5	33.3	31.0	31.3	32.0	31.1
35	30.5	32.9	30.3	29.5	30.5	30.3

The data in the above Table as well as in Table XIX of the Appendix, show that there was a gradual increase in ginning percentage with the age of the boll, attaining its maximum value by about the 27th day after flowering, when the curves of relative rate of growth of lint index and seed weight intersected each other and thereafter there was a gradual fall on account of higher relative rate of growth of seed till the boll matured. Thus the ginning percentage of the *kapas* in a fully matured boll is about 2 to 4 percent less than what it was a week before the opening of the boll. The highest values occurring in the Table IV have been underlined.

From the trend of rise and fall of ginning percentage it would be again noticed that though Sind Sudhar manifested an appreciable lag in ginning percentage in the beginning, it touched its maximum at practically the same time as M-4 did, but it, eventually, lost its superiority in ginning outturn to M-4 because of higher rate of development of seed in the later stages. Taking the mean of three seasons, while M-4 experienced a loss of 2.2 per cent in ginning outturn, Sind Sudhar exceeded this figure by 1.4 per cent.

(b) *Developmental changes in fibre properties*

The actual data pertaining to the different fibre properties are given in Table XX to XXIII.

*Mean fibre length*

The values of mean fibre length were examined statistically by the method of analysis of variance, primarily to isolate the variance due to age. The analysis of variance is given in Table V showing the contribution of variance due to various factors and their significance.

TABLE V  
*Analysis of variance of mean fibre length*

Due to	D. F.	S. S.	M. S.	Ratio	Significance
Cottons . . . . .	1	.006229	.006229	15.418	**
Years . . . . .	2	.008711	.004356	10.782	**
Ages . . . . .	8	.025000	.003125	7.735	**
<i>First order inter-actions—</i>					
Cottons × years . . . . .	2	.003971	.001986	4.915	*
Cottons × ages . . . . .	8	.004838	.000605	1.498	N.S.
Years × ages . . . . .	16	.005989	.000374	..	..
Error . . . . .	16	.006462	.000404	..	..
<i>Total</i> . . . . .	53	.061200	..	..	..

\*\* Significant at  $P = .01$

\* Significant at  $P = .05$

It will be seen from Table V that contrary to general expectation, the mean fibre length exhibited some variability with age even during the second phase of boll development. In order to see if this variability was in any way due to high sampling error or otherwise, the variance due to ages was further split up into linear and quadratic components by fitting polynomials to the mean values of three seasons for each cotton. The procedure followed for fitting the polynomials was the sum and difference method given by Fisher [1925].

The contribution of each component is shown in Table VI.

TABLE VI  
*Analysis of variance of mean fibre length due to ages*

Polynomial term	D.F.	M-4			Sind Sudhar		
		S. S.	M. S.	Ratio	S. S.	M. S.	Ratio
Linear . . .	1	·003672	·003672	11·208*	·013260	·013260	22·211**
Quadratic . . .	1	·001173	·001173	3·580	·006282	·006282	10·524*
Error . . .	6	·001965	·000327	..	·003582	·000597	..
<i>Total</i> . . .	8	·006810	..	..	·023124	..	..

It is clear from Table VI that most of the variance due to ages is contributed by the linear component in the case of M-4 and both linear and quadratic components in the case of Sind Sudhar. Thus, there is a strong evidence that the lengthening phase of both the cottons had not ceased by the 19th day of their age, which is just the first half of boll maturation period. Thus Ball's [1915] inference from his study on Strain 77, (*G. barbadense*), that the lengthening phase finishes by the first half of maturation period of a boll, is not corroborated by the above study. The fact is that there was a significant increase in the mean fibre length of both the varieties from 19th to 25th day. This increase was more pronounced in the case of Sind Sudhar, which exhibited a parabolic rise in this period. This explains, also, the higher relative rate of growth of the lint index of Sind Sudhar in the beginning of the second phase of boll development.

During this period, when elongation of fibres was still taking place, the cellulose deposition had started simultaneously as would be clear in the further analysis of other fibre properties. This supports the view of Gulati and Ahmad [1945] who suggested that the two phases of development overlap to some extent.

It is interesting to note the difference in the elongation period of two cottons. While both of them matured practically in the same period, M-4 took a lead over Sind Sudhar in completing its first phase a few days earlier than the latter. This shows a difference in the rate of lengthening, which was greater for M-4 than for Sind Sudhar.

#### *Mean fibre weight per unit length*

Logistic curves were fitted to the values of mean fibre weight per unit length of the whole fibre and of middle section. The procedure adopted was the same as explained in the case of seed characters.

The calculated values of mean fibre weight per unit length of whole fibre and of middle section for both the cottons are given in Tables VII and VIII.

TABLE VII

*M-4 : Mean fibre weight per unit length in  $10^{-6}$  oz. (calculated)*

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
19	·0669	·0703	·0618	·0639	·0490	·0481
21	·0810	·0854	·0808	·0861	·0746	·0751
23	·0957	·1011	·1023	·1090	·1000	·1027
25	·1105	·1169	·1211	·1300	·1197	·1245
27	·1246	·1318	·1366	·1473	·1324	·1386
29	·1374	·1454	·1483	·1601	·1395	·1460
31	·1485	·1572	·1567	·1691	·1433	·1507
33	·1580	·1671	·1624	·1750	·1453	·1528
35	·1657	·1751	·1661	·1789	·1461	·1538

TABLE VIII

*Sind Sudhar : Mean fibre weight per unit length in  $10^{-6}$  oz. (calculated)*

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
19	·0443	·0434	·0458	·0454	·0444	·0440
21	·0619	·0616	·0625	·0632	·0586	·0587
23	·0813	·0823	·0808	·0830	·0740	·0748
25	·1000	·1031	·0988	·1027	·0895	·0909
27	·1160	·1215	·1147	·1201	·1037	·1055
29	·1283	·1362	·1275	·1340	·1157	·1177
31	·1370	·1467	·1371	·1442	·1252	·1272
33	·1428	·1539	·1438	·1512	·1323	·1341
35	·1465	·1586	·1484	·1558	·1374	·1390

It will be noticed from the above Tables that the rise in mean fibre weight per unit length was very pronounced in the beginning of the second phase of boll maturation. The mean fibre weight per unit length of middle section was higher than that of unit length of the whole fibre all through the process of cellulose deposition. Ahmad [1942] had also found that the weight of the middle section of the collapsed mature hair is higher than that of the whole fibre. It is interesting to note that the difference between the fibre weight of whole fibre and of middle section increased systematically with the advance in the age of the boll. The following Table shows the respective differences for both the cottons.

TABLE IX

*Difference between mean fibre weight per unit length of middle section and whole fibre in  $10^{-6}$  oz. at different ages of boll (raw data)*

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	+002	+002	-002	-003	*000	-001
21	+007	+005	+004	+005	*000	+000
23	+005	+006	+001	+000	+002	+001
25	+008	+010	+005	+003	+005	+002
27	+006	+011	+007	+005	+002	-001
29	+007	+009	+006	+009	+007	+003
31	+011	+012	+005	+009	+006	+001
33	+008	+011	+008	+011	+009	+002
35	+008	+017	+010	+013	+007	+002

In order to see if these differences were significant, the above data were analyzed for different sources of variance, and the analysis is given in Table X.

TABLE X

*Analysis of variance of difference between mean fibre weight per unit length (middle section and whole fibre)*

Due to	D. F.	S. S.	M. S.	Ratio	Significance
Cottons . . . . .	1	·00015000	·00015000	23·9	**
Seasons . . . . .	2	·00015544	·00007772	12·4	**
Ages . . . . .	8	·00045166	·00005646	9·1	**
<i>1st order inter-action—</i>					
Cottons × seasons . . . . .	2	·00003611	·00001806	2·89	..
Cottons × ages . . . . .	8	·00002967	·00000371	0·6	N.S.
Seasons × ages . . . . .	16	·00005090	·00000318	0·5	N.S.
Error . . . . .	16	·00010022	·00000626	..	..
<i>Total</i> . . . . .	53	·00097400	..	..	..

In order to see if the trend of the increase in the differences was recti-linear or curvi-linear, the sum of squares due to ages was further split up into various factors and the analysis is given below :

TABLE XI

*Splitting of sum of squares into various terms*

Term	D. F.	S. S.	M. S.	Ratio
Linear . . . . .	1	·00041387	·00041387	555·5**
Quadratic . . . . .	1	·00003301	·00003301	44·3*
Error . . . . .	6	·00000477	·00000079	..
<i>Total</i> . . . . .	8	·00045165	..	..

It is clear from the above analysis that not only did the difference increase with the age of the boll, but that there was a parabolic rise in the beginning of the second phase, showing a higher rate of deposition in that period. This point has further been substantiated in greater detail on working out the relative rate of increase of mean fibre weight per unit length of middle section and of whole fibre. The relevant values for both the varieties are given in the following Tables :

TABLE XII

*M-4 : Relative rate of increase of mean fibre weight per unit length*

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
20	·09561	·09728	·13403	·14909	·21016	·22276
22	·08338	·08436	·11796	·11793	·14651	·15649
24	·07185	·07258	·08436	·08808	·08996	·09627
26	·06013	·05998*	·06020	·06247	·05036	·05364
28	·04885	·04911	·04110	·04166	·02614	·02802
30	·03885	·03903	·02753	·02736*	·01342	·01376
32	·03100	·03054*	·01788	·01714	·00690	·00695
34	·02376	·02338*	·01127	·01103	·00309	·00328

TABLE XIII

*Sind Sudhar : Relative rate of increase of mean fibre weight per unit length*

Age of boll in days	1942		1943		1944	
	Whole fibre	Middle section	Whole fibre	Middle section	Whole fibre	Middle section
20	·16727	·17509	·15544	·16539	·13875	·14413
22	·13631	·14486	·12840	·13626	·11666	·12118
24	·10351	·11266	·10056	·10648	·09508	·09746
26	·07421	·08208	·07460	·07825	·07367	·07443
28	·05039	·05711	·05284	·05486	·05466	·05477
30	·03280	·03712	·03631	·03669	·03948	·03879*
32	·02073	·02399	·02388	·02369*	·02758	·02642*
34	·01276	·01504	·01573	·01496*	·01892	·01794

The above Tables and the graphic representation in Figs. 5 and 6 clearly show that the middle section of the fibre was not only heavier than the whole fibre all through the process of cellulose deposition but even the relative rate of increase of middle section was greater than that of the whole fibre during different stages of the second phase of boll maturation except in a few cases marked by asteriks in these Tables.

The initial higher rate of development in Sind Sudhar as compared to M-4 has also been manifested in the corresponding values of fibre weight. On the average, Sind Sudhar showed a tendency to grow at a higher rate than M-4.

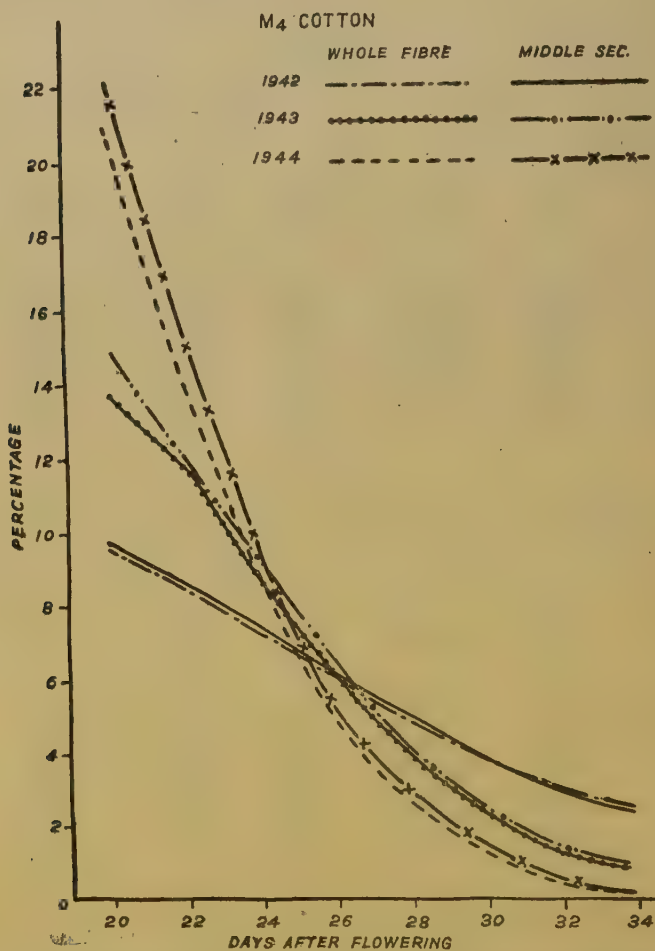


FIG. 5. Relative rate of increase of fibre weight (whole fibre and middle section)

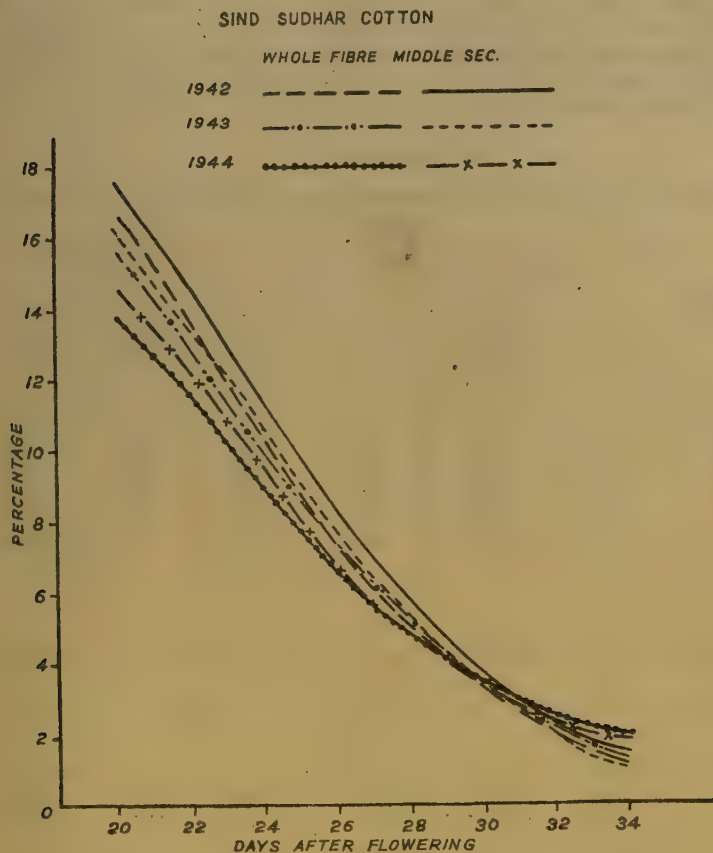


FIG. 6. Relative rate of increase of fibre weight (whole fibre and middle section)

An examination of the above Tables reveals that the seasonal changes are large in M-4 but quite small in Sind Sudhar. For the former cotton the value on the 20th day is about four times as great as the value on the 34th day in 1942, 12 times in 1943 and 70 times in 1944. It is almost constant for Sind Sudhar for which the relative rate of increase on the 20th day is about 12 times that on the 34th day in all three seasons.

On comparing the values of the relative rate of growth of lint index (Tables II and III) and the relative rate of increase of mean fibre weight per unit length of the whole fibre (Tables XII and XIII), it will be observed that the corresponding values of both the characters for different ages lie very near each other except in

the very initial stages. It may thus be inferred that the increase in lint index was mostly due to the increase in cellulose deposition in the fibre, barring a few days in the beginning when the contribution to the lint index had been made by an appreciable increase in length. The values of relative rate of growth of lint index and fibre weight per unit length are given in Tables XIV and XV.

TABLE XIV

*M—4 : Relative rate of growth of lint index and mean fibre weight per unit length (whole fibre)*

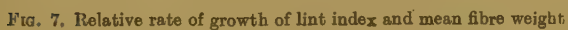
Age of boll in days	1942		1943		1944	
	Lint index	Fibre weight	Lint index	Fibre weight	Lint index	Fibre weight
20	·1268	·09561	·1515	·13403	·1676	·21016
22	·1074	·08338	·1158	·11796	·1330	·14651
24	·0848	·07185	·0824	·08436	·0940	·08996
26	·0648	·06013	·0554	·06020	·0668	·05036
28	·0489	·04885	·0345	·04110	·0440	·02614
30	·0354	·03885	·0218	·02753	·0278	·01342
32	·0240	·03100	·0132	·01788	·0157	·00690
34	·0160	·02376	·0079	·01127	·0092	·00309

TABLE XV

*Sind Sudhar : Relative rate of growth of lint index and mean fibre weight per unit length (whole fibre)*

Age of boll in days	1942		1943		1944	
	Lint index	Fibre weight	Lint index	Fibre weight	Lint index	Fibre weight
20	·1956	·16727	·1669	·15544	·1534	·13875
22	·1563	·13631	·1373	·12840	·1197	·11666
24	·1168	·10351	·1056	·10056	·0903	·09508
26	·0806	·07421	·0770	·07460	·0639	·07367
28	·0505	·05039	·0516	·05284	·0418	·05466
30	·0310	·03280	·0341	·03631	·0276	·03948
32	·0192	·02073	·0229	·02388	·0136	·02758
34	·0100	·01276	·0135	·01573	·0106	·01892

The values of the relative rate of growth of lint index and increase of fibre weight have been also shown in Figs. 7 and 8. Examination of above Tables and the relevant graphs shows that except in the initial stages of the second phase the values of both the characters are very close to each other.



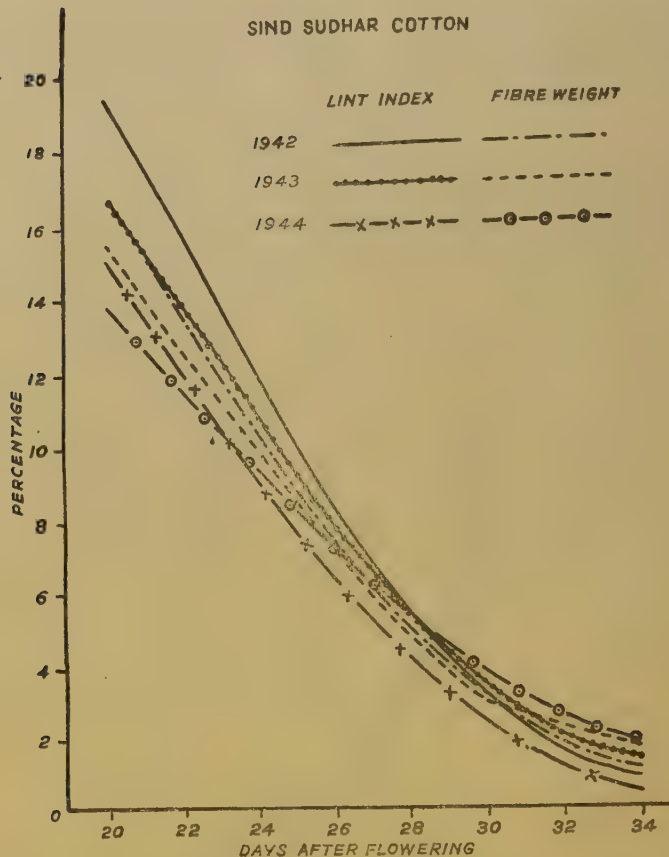


Fig. 8. Relative rate of growth of lint index and mean fibre weight

There is one exception in the case of M-4 for the season 1944-45, when the rate of growth of fibre weight was appreciably higher than that of lint index.

#### *Maturity counts*

Maturity of cotton hair is determined in terms of the amount of cellulose deposition. During the first phase of lengthening, the fibre only elongates in the form of a tube. After this period, thin layers of secondary cellulose are deposited, in the form of concentric rings, within the fibre. Some hairs remain thin walled and are classed as dead or immature. Others which are favourably placed to develop normally, are called mature fibres, while those which develop an intermediate thickness of cell wall, are classed as half mature. Thus the percentage of immature fibres would gradually decrease with the advance in the age of the boll.

Actual percentage of mature hairs are given in Table XXIII of the Appendix. The presence of mature hairs right at the start, i.e., on the 19th day, shows that the thickening of fibre wall had already commenced. This process continued right up to the 35th day. The increase in the percentage of mature hairs was rapid up to the 29th day, after which it slowed down considerably, with the result that only in two cases out of six, namely M-4 in 1942 and Sind Sudhar in 1944, the increase in percentage of mature hairs from 29th to 35th day was significant.

These points will be clearer from the study of the following Table, which records the percentage of mature fibres at different ages in both the varieties.

TABLE XVI  
*Percentage of mature hairs (calculated)*

[ Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
19	6	1	2	1	1	7
21	15	6	11	5	6	19
23	32	23	38	22	26	40
25	54	55	69	56	65	65
27	70	74	80	82	87	28
29	78	79	83	91	93	90
31	82	80	83	93	94	93
33	83	81	83	94	94	94
35	83	81	83	94	94	95

On comparing the maturity counts with mean fibre weight per unit length (whole fibre), as given in Table XXI of the appendix, it will be noticed that the changes in fibre weight and maturity are of a similar nature. Most of the fibre weight, like maturity, was acquired up to the 29th day. In two cases out of three an increase in fibre weight after 29th day was accompanied by a rise in maturity. The third case was on the border line of significance. In a few cases it was noticed that though there was practically no increase in maturity, fibre weight showed a steady rise. It could be suspected that this increase might be due to the development of immature hairs into half mature, but this could not be substantiated by the data, which revealed no change in the number of immature and half mature fibres.

Thus, the rise in the mean fibre weight per unit length after the full maturity of the cotton, might be due to the increase in the cell sap in the lumen or some dried residue of boll fluid on the surface of the fibre,

## SUMMARY

Study of the growth of certain seed and lint characters during the second phase of boll maturation was undertaken for two Sind American cottons at the Cotton Research Station, Mirpurkhas, Sind.

Differential trends of seed weight and lint index were observed. In the beginning of the second phase of boll maturation, the relative rate of growth of lint was high followed by a rapid fall in the later stages; but the relative growth rate of seed, though initially much lower than that of the lint, persistently maintained itself with only a slight and gradual fall. Thus the two growth curves gradually converged to a point by about the 27th day after flowering and after intersecting, diverted from each other. This phenomenon was observed in the two varieties at the same stage of boll maturation during the three seasons under investigation. Thus the growth trends of lint and seed were found to be fundamentally different and were unaltered by seasonal fluctuations in lower Sind. However, the angle of intersection was more acute in M-4 than in Sind Sudhar, indicating comparatively less pronounced differences in the growth rates of lint and seed in the former than in the latter.

Maximum ginning percentage for both the varieties was also found to coincide with the day of intersection of the growth curves of seed and lint, falling by two to four per cent in the later stages on account of higher rate of seed development as compared with that of lint.

There was an appreciable increase in the mean fibre length up to the 25th day after flowering. This increase was more pronounced in the case of Sind Sudhar than M-4. Since there was an evidence that cellulose deposition inside the fibres started even before the 19th day it could be inferred that the two phases of development, namely lengthening and thickening, overlapped for some time.

Mean fibre weight per unit length of the middle section was more than the mean fibre weight per unit length of the whole fibre during all stages of the second phase of boll maturation; even the relative rate of growth of the former was higher than that of the latter in most of the cases.

Maturity counts were higher in Sind Sudhar than in M-4 by 10 per cent. Although the maximum values of mature fibres for both the varieties were attained on the 35th day after flowering, values very near the maximum had reached by about the 29th day.

## ACKNOWLEDGEMENTS

The author owes a great debt of gratitude to Dr Nazir Ahmad, O.B.E., Ph.D. (Cantab.), J.P., Director, Technological Laboratory, Matunga, Bombay (now member, Indian Tariff Board) for his inspiring guidance and the most valuable suggestions during the course of this study. Thanks are due to Dr R. Sankaran, Cotton Botanist, Cotton Research Station, Mirpurkhas, Sind, without whose co-operation this work would not have been accomplished. To Mr. R. S. Koshal, Statistician, Department of Agriculture, Bombay Government, are due my obligations for his help in statistical interpretation of the results.

The last but not the least, the paper owes its present reproduction and shape to the invaluable suggestions and guidance of Mr Muhammad Afzal, Cotton Botanist, Cotton Research Laboratory, Lyallpur, who, in his most crowded time, helped me not only in going through the MSS, but bringing the real of the matter out in the proper form.

The work was carried out with the financial aid of the Indian Central Cotton Committee, Bombay, which the author acknowledges with gratitude.

## REFERENCES

- Balls, W. L. (1915). *Development and Properties of Raw Cotton*. A. & C. Black Ltd., 68-85  
 Hock, C. W., Ramsay, R. C. and Harris, M. (1941). Microscopic structure of Cotton fibre. *Amer Dyestuff. Rep.* **30**, 53-60  
 Iyengar, R. L. N. (1943). *Indian J. agric. Sci.* **13**, 434-445  
 Ahmad, N., and Nanjundyya, C. (1938). Indian Central Cotton Committee, Technological Laboratory, *Tech. Bull.*, series B, No. **23**  
 Ahmad, N., and Nanjundyya, C. (1936). Indian Central Cotton Committee, Technological Laboratory, *Tech. Bull.*, series B, No. **21**  
 Gulati, A. N., Ahmad, N. (1935). Indian Central Cotton Committee, Technological Laboratory, *Tech. Bull.*, series B, No. **20**  
 Mills, F. C. (1938). *Statistical methods*. Henry Holt & Co., New York, 675-680  
 Fisher, R. A. (1925). *Statistical methods for Research Workers*. Sixth Edition, 125  
 Gulati, A. N., Ahmad, N. (1944). *Indian Farming*. **6**, 1, 9-11

## APPENDIX (RAW DATA)

TABLE XVII

*Seed weight (weight of 100 seeds) in gm.*

Age of boll in days	M-4			Sind Sudhar		
	1942	1943	1944	1942	1943	1944
17	..	3.24	2.72	2.47	2.99	3.09
19	3.46	3.68	3.13	3.06	3.54	3.78
21	4.49	4.49	3.78	3.98	3.94	4.36
23	5.35	5.36	4.54	4.29	4.48	4.91
25	5.62	5.92	5.12	5.02	5.05	5.06
27	6.32	6.83	5.72	5.03	5.70	5.70
29	7.54	7.05	6.70	6.62	6.78	6.36
31	8.41	7.64	6.38	6.96	6.62	6.60
33	8.39	8.32	7.69	7.40	7.98	7.67
35	9.20	8.62	7.17	8.21	8.04	7.40

TABLE XVIII

*Lint index (weight of lint on 100 seeds) in gm.*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
17	..	1.03	0.68	0.56	0.75	0.81
19	1.30	1.59	1.08	0.90	1.12	1.15
21	2.16	2.25	1.62	1.62	1.59	1.67
23	2.63	2.78	2.05	2.08	1.99	2.20
25	2.73	3.14	2.48	2.42	2.51	2.25
27	3.26	3.42	2.90	2.59	3.11	2.72
29	3.62	3.70	3.00	3.32	3.36	3.05
31	3.92	4.01	2.92	3.39	3.34	3.08
33	3.91	4.13	3.24	3.48	3.72	3.35
35	4.07	4.25	3.28	3.56	3.48	3.36

TABLE XIX

*Ginning percentage*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
17	..	24.1	20.0	17.1	20.0	20.8
19	27.3	30.1	25.6	22.8	24.0	23.8
21	32.4	33.4	30.0	29.0	28.7	27.7
23	32.8	34.1	31.1	32.6	30.8	30.9
25	32.7	34.7	32.6	32.5	33.2	30.8
27	34.0	33.4	33.6	34.0	35.3	32.3
29	32.6	34.4	30.9	33.4	33.1	32.4
31	31.8	34.4	31.2	32.8	33.5	31.8
33	31.8	33.2	29.9	32.0	31.7	30.4
35	30.7	33.1	31.4	30.2	30.1	31.2

March, 1949 ]

DEVELOPMENT OF COTTON SEED AND LINT

TABLE XX

*Mean fibre length in inches*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
19	0.98	0.93	0.95	0.87	0.87	0.95
21	0.97	0.96	1.01	0.90	0.96	0.97
23	0.96	0.95	1.00	0.92	0.99	0.99
25	1.00	1.00	1.02	0.96	1.00	0.97
27	0.99	0.98	1.01	0.97	0.96	0.96
29	0.98	0.96	1.04	0.98	1.00	1.01
31	1.00	0.98	1.00	0.96	0.97	1.00
33	1.00	0.96	1.03	0.99	1.00	1.01
35	0.98	1.00	1.02	0.97	0.99	0.96

TABLE XXI

*Mean fibre weight per inch in  $10^{-6}$  oz. (whole fibre)*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
19	.064	.061	.051	.044	.046	.043
21	.080	.081	.075	.061	.064	.060
23	.104	.106	.092	.084	.078	.078
25	.108	.122	.118	.099	.096	.089
27	.130	.134	.136	.113	.120	.107
29	.135	.150	.138	.134	.126	.114
31	.152	.157	.139	.140	.143	.119
33	.154	.164	.149	.142	.146	.139
35	.166	.164	.147	.144	.140	.139

TABLE XXII

*Mean fibre weight per inch in  $10^{-6}$  oz. (middle section)*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
19	·066	·063	·049	·041	·046	·042
21	·087	·086	·079	·066	·064	·060
23	·109	·112	·093	·084	·080	·079
25	·116	·132	·123	·102	·101	·091
27	·136	·145	·143	·118	·122	·106
29	·142	·159	·144	·143	·133	·117
31	·163	·169	·144	·149	·149	·120
33	·162	·175	·157	·153	·155	·141
35	·174	·181	·157	·157	·147	·141

TABLE XXIII

*Percentage of mature hairs*

Age of boll in days		M-4			Sind Sudhar	
	1942	1943	1944	1942	1943	1944
19	5	1	2	1	1	1
21	20	9	17	14	11	11
23	46	50	42	48	32	42
25	62	56	68	62	68	74
27	64	73	79	73	81	76
29	72	79	86	90	94	83
31	80	82	81	94	94	90
33	80	77	85	93	96	97
35	88	82	84	94	92	96

## THE SURVEY OF *POLLU* AND ROOT DISEASES OF PEPPER

By K. KRISHNA MENON, Assistant Mycologist, Indian Council of Agricultural Research

(Received for publication on 22 May 1946)

THIS paper comprises an account of the studies made during a survey of pepper cultivation in South Western India undertaken under the auspices of the Imperial (Indian) Council of Agricultural Research and the Madras Government. The survey was carried out between June and December 1944. During the survey, pepper gardens were visited in Malabar and South Kanara districts of Madras, Coorg, North Kanara district of Bombay Province, and the States of Travancore, Cochin and Mysore. The object of the survey was to assess the importance of *pollu* (hollow berry disease) and root diseases of pepper to the decline of the pepper industry in India. An exhaustive enquiry was made on the role of pests and diseases. Enquiries were also made and observations recorded on the yield of pepper in relation to different tracts, varieties under cultivation, systems of cultivation and manuring, choice of standards and the price trends. The facts elicited during the survey showed that despite the importance of pests and diseases in certain tracts, there existed a variety of agricultural and marketing problems, the solution of which alone would rehabilitate a declining industry. Hence the paper attempts to furnish a comprehensive account of the reasons for the decline of pepper in India and to suggest ways and means to overcome them. Advantage was taken of the survey to make a collection of the available varieties of pepper both cultivated and wild and to propagate them."

Pepper or the 'black pepper' of commerce (*P. nigrum*) is indigenous to the forests of Travancore and Malabar where it has been found growing wild in the rich moist humus soils of the submontane tracts. The crop has been in cultivation in South India from time immemorial. The spice was known and esteemed from the earliest times as evidenced from references to it in ancient Sanskrit literature. It was highly valued by the Romans and for centuries formed an article of trade between India and Europe. It was so highly valued that sometimes it replaced money in certain transactions. Payments of rent used to be made in pepper and often ransom demanded included pepper besides gold and silver. There can be little doubt that the high price of pepper provided one of the main incentives for search to be made for an all-sea-passage to India, and Vasco de Gama's achievements by his discovery of a route to the West Coast of India led to this spice becoming a Portuguese trade monopoly until the seventeenth century. India continued to be the seat of pepper cultivation till the 19th century during the latter part of which the cultivation of pepper was extended to the Malay Archipelago, where it became so thoroughly established that the seat of the pepper industry of the world shifted to this part of the world.

*Distribution, climate, rainfall and elevation*

Pepper is purely a tropical plant and thrives best in places where the annual rainfall is well over 80 inches per annum and never less than 50 to 60 inches. It prefers a warm and moist atmosphere which is the normal feature of the pepper belt of the West Coast extending from South Travancore in the south to Konkan in the north. The cultivation of pepper is mainly confined to the slopes and lower altitudes and submontane tracts of the Western Ghats. Travancore and Malabar are the most important producing tracts. In parts of South Kanara it is cultivated on a fairly large scale. It is also grown to some extent in Coorg, Mysore, Cochin, and the North Kanara district of the Bombay Presidency. It is also found, grown on a small scale, in Assam and Bengal. Outside India, pepper is extensively cultivated in East Indies, Malaya, the Straits Settlements, Java and the Dutch East Indies. Though introduced from India, pepper now forms one of the most important products of export from these countries.

Pepper is found growing from sea level to an altitude of well over 3,500 feet above the mean sea level. As regards temperature there are no records available for all the pepper growing tracts but from the knowledge of conditions in some, it can be assumed that the maximum temperature during the hot weather will seldom be over 104°F. and the lowest temperature which is reached during the months of December to January may be as low as 50°F. Thus it is seen that within these wide limits, the pepper plant can stand a fairly wide fluctuation of temperature

*Distribution on the West Coast of India*

The pepper growing tracts on the West Coast may be roughly classified as follows :

- I. The coastal area where pepper is grown in almost every 'compound' or plot of land in which a residential building is situated, but where it is seldom cultivated as a pure crop. The number of vines in each compound varies considerably, it being anything from 10 to 100.
- II. The slopes and hill valleys where pepper is extensively cultivated as the main crop.
- III. The foot of the hills where pepper thrives best and gives the heaviest yield.
- IV. The Wynaad hills at elevations ranging from 2,000 to 3,500 feet where the crop is extensively grown interplanted with coffee (*C. arabica*). In recent years pepper in this tract has been on the decline and Arabica coffee is replaced by Robusta coffee (*C. robusta*) and loose-jacket oranges (*C. nobilis*).

*Homestead compounds*

Both in Malabar and Travancore, almost every compound contains some pepper vines. The number in each compound varies considerably. These vines are mostly trained on mango, jack, areca palm, coconut or any available tree which serves as a good standard. These vines are usually situated far and wide and they

are seldom found suffering from any serious pest or disease. Almost every household in Malabar, Travancore and Cochin is self-sufficient as regards pepper and after meeting its domestic needs the surplus is sold and this is one of the few cash crops of the tract. The produce from the vines formed in these innumerable small compounds contribute very largely to the total production. In the words of the Director of Agriculture, Travancore—

‘Very many regular plantations of pepper do not exist here, but pepper grown as a garden crop occupies not an inconsiderable area. The produce from such isolated garden crops constitute by far the largest share of the exports of this commodity which vary in recent years between 40,000 and 50,000 candies (of 500 lb.) of dry pepper annually.’

#### *Cultivated area*

Pepper is extensively cultivated in and below the Western Ghats and due to various systems of cultivations which are described later in this report, it is not easy to get at very accurate figures of the acreage under this crop. Only a rough estimate of the area under pepper can be given.

TABLE I  
*Showing the area under pepper in the different tracts*

Tract	Area in acres
1. Malabar . . . . .	94,685
2. Travancore . . . . .	89,159
3. South Kanara . . . . .	8,570
4. North Kanara . . . . .	2,500
5. Coorg . . . . .	1,122
6. Mysore . . . . .	500
7. Cochin . . . . .	250
Total . . . . .	196,806

#### *India's place in the pepper trade*

Pepper is a commodity in which India had for several years held a predominant place in the world's market. The West Coast of India enjoyed a practical monopoly till the beginning of the nineteenth century when there started a keen competition from the Malay Archipelago. It is a crop of great commercial importance to Madras Presidency since Madras has always taken a preponderating share of the trade in India in pepper as seen from the following Table :

TABLE II

*Showing the contribution of Madras Province to the export trade of British India*

Year	Quantity in cwt.		Value in rupees	
	India	Madras	India	Madras
1933-34 . . . . .	58,909	50,533	18,23,903	14,54,464
1934-35 . . . . .	74,070	60,681	24,50,390	18,87,594
1935-36 . . . . .	26,415	24,939	7,62,852	7,06,574
1936-37 . . . . .	24,977	23,326	6,08,850	5,64,340
1937-38 . . . . .	17,456	16,148	3,91,616	3,57,762

In recent years, South India which was once the leader in pepper trade has fallen to the lowest and it contributes only about 2 to 3 per cent to the world export trade as can be seen from the following Table culled from the International Year Book of *Agricultural Statistics* [1938-39].

TABLE III

*Annual export of pepper from some important producing countries*

Countries	Quantity in metric tons					
	1933	1934	1935	1936	1937	1938
1. Netherlands Indies . . .	44,330	48,495	58,747	78,399	31,266	54,814
2. British Malaya . . . . .	16,211	20,437	22,673	10,939	10,885	7,749
3. Java . . . . .	5,852	4,039	5,011	5,814	1,961	4,575
4. Indo-China . . . . .	3,679	4,002	3,434	3,901	3,852	5,705
5. Sarawak . . . . .	3,314	4,765	1,766	2,050	2,209	3,061
6. Others . . . . .	38,478	44,466	53,736	72,585	29,315	50,239
7. India . . . . .	3,045	3,343	2,846	722	1,215	703
Total . . . . .	1,14,909	1,29,537	1,48,213	1,74,413	80,693	1,26,846
India's share (percentage) . .	2.65	2.58	1.92	0.41	1.50	0.55

## BOTANICAL DESCRIPTION

The pepper plant (*Piper nigrum*, L.) belongs to the natural order *Piperaceae* or pepper family to which also belong the betel vine (*P. betle*) *Thippili* (*Piper longum*) and the *Valmulaku* or the tailed-pepper (*Piper cubeba*).

It is a perennial climbing shrub attaining a height of about 30 feet. The vines are usually trained on various straight-stemmed trees known as 'standards,' whose trunks are clothed with the climbing stems, branches and foliage of the vines. The stems are usually swollen at the nodes, a character which can be seen even in the very older portions. From these swollen nodes numerous adventitious roots commonly called 'clinging roots' or 'climbing roots' are produced, by means of which the plants attach themselves to the standards and climb up the standards to expose their leaves to the maximum light and air. As the stems grow older they become woody with well-developed bark. Pepper plants are long-lived and vines 50 to 60 years old are seen in some parts of Malabar.

The leaves are alternate and simple. Each leaf has a short petiole and a broad oval entire lamina ending in a short acuminate tip. The colour of the leaves varies from light to dark green, shiny on the upper surface but paler and coarse underneath. A leathery texture and pungent taste are characteristic of pepper leaves. Plants grown under shade as in Wynaad remain evergreen but when the shade is not sufficient a partial shedding of leaves is evident in the dry months from March to May. With the advent of summer showers new flush is put forth and flower spikes are subtended from the axils of the new leaves.

The flowers are minute and are produced in several rows on elongated catkins popularly called 'spikes'. The length of the catkin varies with different varieties. The flowers are not showy. They are usually bisexual but some varieties bear dioecious unisexual flowers. Cultivated varieties have usually a higher percentage of bisexual flowers. No variety can be called first rate unless the flowers in a spike are mostly hermaphrodite. Each flower is subtended by a shield-like bract and a smaller bracteole. The perianth parts are absent. In hermaphrodite flowers two stamens are visible, one on each side of the central pistil. Each stamen has a short stalk surmounted by a bilobed anther. The ovary is unilocular with one ovule in it. The style is not conspicuous and is reflexed crosswise from the apex of the ovary. There are four to five stigmatic branches.

The fruit is sessile and berry-like, green when young but ripening into a cherry colour. The outer rind is firm at first, but when the berries ripen it becomes soft and pulpy and easily sloughs off, exposing the hard coat of the single seed. When mature the spike bears several rows of close-set berries.

The factors which determine the yield are mainly (1) the number of spikes in a vine; (2) the length of the spike; (3) the number of berries per unit length; and (4) the number of rows of berries and the density of the berries.

*Flushing and pollination*

Pepper vines resume their activity after the hot summer months during which there is practically no growth and many leaves are shed. Soon after the commencement of the south-west monsoon the early symptoms of flushing are evident, first in the form of a minute non-elastic brownish cap from the ends of the fruiting branches of the previous season. This cap-like structure is pushed up by the growing sheath underneath. It is sickle shaped and it usually falls off within ten to twelve days of its appearance. Then a minute spike can be seen with a tiny young leaf subtending it. The colour of this leaf is creamy white but the normal green colour gradually develops within six weeks. Anthesis begins about two to three weeks after flushing, and proceeds from the base of the spike to the tip. It takes about a week for all the flowers on a spike to be completely open. The opening of the flowers takes place all the 24 hours of the day though it is more active in the early morning and late in the evening.

The number of flowers in different varieties varies mainly depending on the size of the spikes and the number of flowers per unit length of the spike. The lengthening of the spike is most marked during the period of flower opening. The agency that scatters the pollen grains in different directions and helps in pollination of the flowers, seems to be the heavy driving rains of the monsoon. The number of pollen grains carried by a single spike is estimated at 500,000 to 750,000 and this gives an idea of the large number of pollen grains produced in pepper gardens during the flowering period. One pollen grain being enough to fertilize an ovary, there is ample reserve of pollen for accidental dispersal.

The flowers of pepper are protogynous and the interval between the appearance of the stigmas and the period of discharge of the pollen grains varies considerably. It is found that the stigmas of pepper flowers remain receptive for a period of 2 to 10 days depending on the variety. Generally the flowers of pepper are not self-fertilised but there is a chance for the flowers at the tip of the spike being self-fertilised by pollen grains discharged from stamens at the bases.

## VARIETIES OF PEPPER

Many varieties of cultivated pepper exist. Each tract has its own selection of popular varieties which should have come into existence as true seedlings. Those which are easily distinguishable go by different names in the tracts of their origin. Introductions have taken place from one tract to another with the result that one and the same variety goes under different names in the different areas. For the purpose of this report the varieties found in each of the important pepper tracts will be considered separately. So far no variety of pepper existing in India has been produced as a result of human effort at breeding.

-(A) *Malabar and South Kanara districts*

In this tract eight varieties are under cultivation. Some of these are grown over a large acreage while others are confined to particular portions of this tract. The following is a short account of the varieties found in this tract.

(1) *Balamcotta*. This is easily the most popular variety in Malabar and is extensively cultivated in the taluks of Kottayam, Chirakkal and Kurumbranad. It is a medium climber and enjoys the reputation of being a heavy yielder with regular annual bearing capacity. The leaves of this variety are very large in size, easily being the largest of all the varieties—measuring on an average  $19 \times 11$  cm., and comparatively light green in colour. The leaves are oval, being broadest in the middle but the two halves are unequal, one half being broader than the other. The spikes are 12.5 to 19.5 cm. long with big berries. The skin of the berries is thick and the berries are lighter in weight, bulk for bulk than *Kalluvalli*.

(2) *Kalluvalli* (*Kalbu*=stone). Next in importance to *Balamcotta* is *Kalluvalli* which has a fairly wide distribution in this tract. It is a hardy variety and is reported to withstand unfavourable weather conditions better than *Balamcotta*. The yield is good and bearing annual. The leaves are smaller than those of *Balamcotta* measuring on an average  $17.0 \times 9.1$  cm. and are of a dark green colour. They have a tendency to be in line with the internode just below their origin. The spikes vary in length from 8.5 to 17.0 cm. but the berries are very closely set. As the name indicates the berries are heavier and bulk for bulk they register a higher weight than *Balamcotta*.

(3) *Cheriakodi* (*Cheria*=small). This is common in the taluks of Chirakkal and Kottayam and is widely distributed. True to its name the plants of this variety are smaller in size in all parts. The leaves measure  $15.5 \times 6.75$  cm. and are dark green in colour. These project out horizontally more or less at right angles to the stem. The spikes are short, measuring 5.5 to 9.5 cm. in length. The berries though smaller than those of the two foregoing varieties, are close set and packed. This variety is not regular in bearing though in some years it gives a good yield.

(4) *Uthirancotta* (*Uthiran*=shedder). This is not a popular variety though its presence is tolerated in some of the gardens. It is a poor yielder. The leaves are dark green in colour and measure  $16.2 \times 8.4$  cm. The foliage exhibits some resemblance to that of *Kalluvalli*. A large number of vegetative runners are produced at the base. The spikes are  $10.5 \times 19.0$  cm. long, but the berries are sparse though large in size. Hence each spike produces a few berries and this affects yield adversely.

(5) *Karinkatta*. This is cultivated in the Wynaad taluk of Malabar and is mostly found in the neighbourhood of Manantoddy. This is a promising variety which exhibits regular bearing and yields well. Moreover it is not as easily affected by unfavourable seasonal conditions as the other varieties. It is a hardy variety living up to forty years. The leaves are very tough, dark green in colour and project out horizontally and measure  $16.4 \times 9.5$  cm. The spikes measure 7.0 to 11.5 cm. Though short, they are well packed with medium-sized berries. When fully grown, the spikes become twisted in their axis and curved.

(6) *Kallu-Balamcotta*. This variety is popular in the Kottayam taluk of Malabar district round Mattanur and Iritty. It exhibits a combination of the

chief characters of both *Kalluvalli* and *Balamcotta*. It is regular in bearing and gives a heavy yield. The leaves are as big as those of *Balamcotta* measuring  $19.75 \times 12.58$  cm. The spikes are short and the berries are close set and well packed as in *Kalluvalli*. A few vines of this variety were also found growing in some of the coffee plantations in Coorg.

(7) *Malavalli*. This variety is grown in the vicinity of Mattanur and Iritty in the taluk of Kottayam. It has a general resemblance to *Balamcotta* but is irregular in bearing. The leaves, though big ( $18.25 \times 11.65$  cm.) as in *Balamcotta*, are of a dark green colour. The spikes are 12.0 to 18.0 cm. long and the berries are close set. But the irregularity of its bearing makes it an undesirable variety.

(8) *Kottavalli*. This enjoys the greatest popularity among the South Kanara pepper growers. It is a very regular annual bearer giving heavy yield. There is a great resemblance to *Balamcotta* of Malabar and it appears that it is the same variety going under a different name in South Kanara.

#### (B) *Travancore*.

In this part of the country are grown at least a dozen varieties and most of these are peculiar to this area and are not found indigenous in Malabar or South Kanara.

(1) *Kottanadan*. This is one of the popular varieties of Travancore and is largely grown in the South and Central Travancore. It is a hardy variety which comes up well even in areas of less than 80 inches of rainfall. It is a good climber with regular bearing habits and gives a heavy yield. The leaves measure  $14.0 \times 8.0$  cm. The spikes are 7.0 to 13.5 cm. long with close-set medium-sized berries. When mature a twist is developed in the spike as a result of which five twisted rows of berries are borne in each spike. This variety is known in some places as 'ayimpirigan' meaning one with five twists. Occasionally some spikes exhibit branching, and 3 to 5 branchlets may be given off from each spike.

(2) *kaniakadan*. This is more common in tracts in Central and North Travancore which receive a heavier rainfall than the south. It is easily the best variety of the State and is a great favourite of the planters and the traders. Among traders it goes by the name of 'Palai pepper' (after the name of a town in Central Travancore and usually fetches a premium of Rs. 10 per candy of 500 lb.). Two types of this variety are in existence—*Valia Kaniakadan* and *Cheria Kaniakadan* and between the two the former is more extensively cultivated. Both are good yielders and bear annually. The leaves measure  $14.0 \times 6.0$  cm. The spikes vary in length from 7.5 to 16.5 cm., *Cheria Kaniakadan* as the name implies has shorter spikes and smaller leaves.

(3) *Perumkodi*.—This is cultivated in Central and North Travancore. It is also known to be a good yielder, bearing yearly. The vines are sparsely leaved and the leaves measure 13.0 × 7.0 cm. The spikes vary in length from 10.5 to 17.5 cm.

(4) *Karivilanchi*.—Though it is found all over the State, it is more common in Central and South Travancore. It is a hardy plant exhibiting a great resemblance to *Kalluvalli* of Malabar. It is favoured by the cultivators and traders. This variety usually gives a good yield and bears yearly. The leaves are dark green in colour and measure 12.5 × 8.0 cm. The spikes vary in length from 6.0 to 14.0 cm. and is closely packed with medium sized berries.

(5) *Karivalli*—(*kari*=dark).—This is also confined to Central Travancore. It is a good climber but irregular in bearing, good yield being obtained in alternate years. The leaves are broad and measure 16.5 × 10.5 cm. The spikes vary in length from 11.0 to 19.5 cm. Though the spikes are long the berries are not close set.

(6) *Mundi*.—This is more common in North Travancore. It is a hardy variety flowering early in the season and coming to harvest in November-December. It bears annually and gives a good yield. The leaves measure 14.0 × 7.5 cm. The spikes vary in length from 7.0 to 13.5 cm. and berries are big sized.

(7) *Munda*.—This is also found in North and Central Travancore and more or less resembles *Mundi* in appearance. It is a medium climber and a poor yielder. The leaves measure 11.5 × 7.5 cm. The spikes vary in length from 6.0 × 14.0 cm. but the berries are big. The produce is harvested in December-January, thus is later than the harvest of *mundi*.

(8) *Thulakodi*.—It is found largely in Central Travancore and is an early variety. It flowers in April to May and is harvested in October-November. It is a medium climber, yearly bearing, and a good yielder. The spikes vary in length from 6.5 to 12.5 cm.

(9) *Arikottanadan*.—It is found in Central and South Travancore and resembles *Kottanadan* except that the berries are smaller in size. The spikes vary in length from 7.5 to 14.0 cm.

(10) *Kuthiravali* (*horse-tail*).—It is found round about Kottarakara and southern taluks. It is a medium climber, yearly bearing and a good yielder. The spikes are long ranging from 11.0 to 17.0 cm. and hence the name. The leaves measure 13.5 × 9.25 cm.

(11) *Karinthakara*. It is found in Central Travancore. It is a bold climber, a good yielder but bears only in alternate years. The leaves measure  $12.0 \times 7.0$  cm. and the spikes vary in length from 5.5 to 13.0 cm.

(12) *Kumbakodi*.—It is confined mainly to Central Travancore. It is a late variety, the produce being harvested in February-March. The name of the variety itself indicates the month of harvest Kumbam (Malayalam)=February-March. It is a hardy plant, bears annually but gives only medium yield. The leaves are rather broad and pale green in colour and measure  $13.5 \times 9.5$  cm. The spikes vary in length from 8.0 to 14.5 cm. The berries are not very thickly set.

(13) *Chumala*.—This is found in Rani and Pattanamthitta. The leaves are broad and large and pale green in colour and measure  $18.5 \times 10.25$  cm. The growing tips have a light pinkish colour and hence the name '*chumala*'. It is an early variety, flowers in April-May with the early rains and is harvested in October-November. The spikes vary in length from 11.0 to 16.5 cm. and the berries are well packed. It is a bold climber.

#### *A spreading variety of pepper*

This variety was found growing in two estates in Travancore State (1) Perumila Tea Estate (Konni) and (2) Malankara Rubber Estate (Todupuzah). It grows like a shrub and does not require a standard. Adventitious roots are not formed at the nodes. A plant five years old was found to have covered an area of six feet in diameter. The leaves are light green in colour and measure  $12.25 \times 9.45$  cm. The flowers are hermaphrodite. The spikes are of medium size and vary in length from 8.0 to 12.0 cm. and fully packed with berries. The berries are small in size and are quite pungent to taste. The owner said that he got  $3\frac{1}{2}$  pounds of dry pepper during the previous season.

The owners were not able to account how this variety got introduced in their estates but they believe that they grow from seeds dropped by birds.

#### *(C) Mysore and North Kanara*

The main varieties under cultivation are the following :

(1) *Malligasara*. This is one of the most common varieties cultivated in North Kanara and Mysore. It is a medium climber, annual bearer and a heavy yielder. The leaves are dark green in colour measuring  $17.75 \times 12.0$  cm. The spikes are medium sized and vary in length from 8.0 to 12.0 cm. and the berries are well packed and close set. It is known as *Mallisara* in North Kanara and is one of the most popular varieties cultivated there, yielding better than other varieties. The berries are very pungent and weigh more than others bulk for bulk.

When ripe the berries are shed and so the crop has to be harvested before the berries ripen. A pale green and a dark green variety go under the same name but the former is the more common and widely cultivated one, while the latter is said to do better in places, where the soil dries up quickly.

(2) *Morata*.—This is not a good variety and is a poor yielder. The leaves measure  $16.40 \times 12.3$  cm. The spikes are short 5.0 to 8.0 cm. long and curved. The berries are small, and individual berries are not shed when ripe, but the spikes fall off quickly, thus rendering the harvest easy.

(3) *Arisina morta*.—This resembles *Morata* except that the berries when ripe are yellow in colour, hence the name.

(4) *Doddiga*.—This is a medium climber with big leaves measuring  $19.35 \times 11.5$  cm. The spikes are medium sized 7.50 to 0.5 cm. long, the berries are big and well packed and close set. It is reported that in years of well distributed and heavy rainfall this variety gives a bumper crop.

(5) *Tattisara*.—This is also a good variety, a good climber and a regular yielder. It is reported that the variety flourishes in comparatively drier situations better than in very moist localities. The leaves are dark green in colour and measure  $15.50 \times 11.5$  cm. and the spikes vary in length from 8.5 to 11.5 cm. Unlike *Mallisara* the berries are not shed when ripe which is an advantage in its favour.

(6) *Vakkal Gooja*.—This is a poor yielding variety and as the name indicates one seeded and only a few berries are formed here and there on the spikes. The leaves are light green in colour and measure  $13.75 \times 8.0$  cm. The spikes are short varying from 5.5 to 8.5 cm. in length. Though an early maturing variety it does not find favour with the ryots because of its poor setting of berries.

(7) *Mottukara*.—This is a bold climber and a regular yielder. The leaves are almost round in shape  $15.0 \times 13.0$  cm. and are dark green in colour and tough in texture. The spikes are short varying from 5.0 to 8.0 cm. The aerial climbing roots take a firm hold on the standard and for this reason the growing shoots do not require tying up to the standard after the first two years. It is, however, a slow grower.

(8) *Varieties introduced from Malabar*.—The two main Malabar varieties *Balamcotta* and *Kalluvalli* which have been introduced both in Mysore and North Kanara some 15 years back are found to do well. At Marathur farm which was originally an arecanut Research Station.

of the Mysore Government, these two varieties are being grown side by side with the indigenous ones, but the introduced varieties were found to have established better and yielded higher than the local ones. The average yield of the Malabar varieties per vine was about 2 lb. while the yield of the locals was from half to one pound. Some of the Malabar vines have given yields of over 5 lb. per vine and they have maintained this superiority in yield for some years. Unfortunately this farm was closed down and sold to a private individual who does not take much interest in the cultivation of pepper. Even now it is found that the majority of the vines in the garden are either *Balamcotta* or *Kalluvalli*. *Balamcotta* appears to thrive better than *Kalluvalli* in this locality. The soil is laterite loam and is well suited for pepper cultivation. The vines receive the benefit of cultivation and manuring given to the arecanut palms. There is scope for extension of these two Malabar varieties, viz., *Balamcotta* and *Kalluvalli* in Mysore as well as in North Kanara. Experienced growers stated that the produce of the Malabar varieties, though they gave higher yield than the local one, were lighter in weight by about six per cent bulk for bulk.

#### *Introduction of new varieties*

From the foregoing notes on the performances of varieties in different tracts it is obvious that introduction of new varieties is advantageous under certain conditions, but it should be done with caution and proper attention should be bestowed on the suitability of the land and the climatic conditions of the locality, where it is proposed to introduce new varieties. The abrupt transition to a different set of climatic conditions may have some adverse effect on the vitality of the vines. In this connection mention should be made of the experience of some growers that cuttings taken from places of higher fertility and heavier rainfall to places of lower fertility and lighter rainfall failed to thrive in their new surroundings.

### PROPAGATION

Pepper can be propagated from seeds and vegetatively from cuttings of the vine. The plantation practice adopted over the whole area is to propagate from cuttings. Propagation from seeds is not only a laborious and uncertain method but also one which will take a longer period for the commencement of flowering and bearing. But it is the one method of evolving new varieties and can be utilized only on research and breeding stations. The pepper growers who are always anxious for quick returns, adopt the vegetative method of propagation only. The technique adopted by the growers varies to some extent in different tracts. The following are some of the methods :

(1) The vegetative shoots or 'runners' as they are commonly called, are taken from the base of the vine. These runners are selected, coiled and kept poised in air in the fork of a stick planted near the parent vine, so that they do not come in contact with the soil. If these are allowed to come in contact with the soil, adventitious roots will be formed at the nodes and the runners will become useless for planting. Experience shows that cuttings which are formed roots at the nodes are not good for planting, since they fail to establish.

All good growers adopt this method but those who depend on outside agencies for the supply of their planting material often get bad or indifferent material. There is no fool-proof method by which the cuttings from desirable varieties could be identified at the initial stage and the performance of the planted material could be known only after about five years when the vines begin to yield. Hence it is essential that the selection of good and quality cuttings should be done at the time of planting as otherwise all the labour and expenses involved will be a waste. One should, as far as practicable, take cuttings from selected vines from his own garden or at least from a reliable planter. The general method adopted by the growers in most of the pepper growing tracts is to plant cuttings. The vegetative shoots from the upper portions of the vine are not as a rule used for planting, as experience shows that it is difficult to get them established on the standards.

#### *Planting cuttings of fruiting branches*

(2) In some localities like Travancore and North Kanara some growers use planting material from the fruiting branches and it is their experience that the plants from these cuttings began to bear even in the second year and produce a sizable crop from the fourth year onwards, while plants raised from vegetative runners begin to yield only from the sixth or seventh year. But as a set off to this precocious bearing the effective bearing period of these plants is reported to be reduced by about three to five years. The total yield of these plants was in no way reduced. Vines so raised were found to produce no vegetative runners or if they were produced, they were very few in number. This method of propagation can be advantageously taken up by those planters who plant pepper as an intercrop in coconut plantations. By this method they get a quicker return than by the ordinary method of planting vegetative cuttings.

One serious drawback, however in the advocacy of this system is the difficulty to get a sufficient quantity of planting material, as the average grower will not easily part with the fruiting branches from a good vine. But to the extent they become available, e.g., when standards are damaged by wind or by other causes, this system can be employed. All the fruiting branches of such vines, if they are of high yielding strains, may be taken and planted in a nursery, and with proper care and attention to watering and shade, most of the planted cuttings can be made to strike roots and enough material can be had for planting during the next season. One or two rooted cuttings will be sufficient for each standard.

#### *Layering*

(3) In most localities of Malabar and South Kanara, the practice of raising layers in baskets is adopted by growers. Shallow bamboo baskets 2 to 3 inches in depth and 6 to 8 inches in width are filled with pot earth or with good surface soil and selected runners are layered. Within 4 to 6 weeks when roots have formed the layers are carefully separated from the parent plant and planted in prepared pits of  $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{2}$  feet, near the base of the standards. Sometimes coconut husks are used in place of baskets. By this method almost cent per cent of the cuttings planted out would get established. This method can be resorted to mostly

to fill up gaps but cannot be practised on a large scale. Transport is an important consideration. One workman cannot carry more than 6 to 8 baskets at a time and hence the layering is best done in the same garden where the layerings have to be planted.

(4) *Rooted cuttings.*—The use of rooted cuttings is made by some planters in Coorg. The cuttings from selected vines are taken and planted in a small nursery at the end of October when the soil is still moist. With proper attention to watering and provision of suitable shade they are induced to strike roots early. Being a small area the planter's personal attention can be bestowed to it. These rooted cuttings are then removed with a ball of earth and planted during the next July. This method is said to give more than 90 per cent success but is not practised on a large scale at present.

(5) *Layerings trained on stakes.*—This is a common practice in gardens where vines are trained on arecanut trees. Stakes of arecanut stem about 6 feet  $\times$  4 inches are driven into the soil about 2 to 2½ feet away from the parent vine and the vegetative runners from the base are trained on to the stakes along the ground and tied. Roots are formed at the nodes, which are lightly covered by soil. As soon as the roots are sufficiently developed, the layers are carefully severed from the parent plant and planted near the base of an arecanut tree. Casualties among such layerings are usually very low and by virtue of an early start in growth they begin to bear earlier than vines raised from ordinary cuttings. Another method adopted in these tracts, is to allow the vegetative runners, from the base of a good vine to creep along the ground towards one of the adjacent arecanut trees, on which a new vine has to be trained. The runners are covered over with soil to the length of two to three internodes, from where rooting takes place. As the runners thus layered grow in length the growing shoot is tied to the arecanut tree selected. When the layering is well established it is severed from the parent vine.

(6) *Nursery for cuttings.*—It is the experience of most pepper planters that failures among ordinary cutting planted directly under the standards is very large. In some cases it is reported that even 60 per cent of the planted cuttings fail to establish. For this reason, the use of rooted cuttings or layered plants is well worth the serious attention of the pepper planter. A large number of small nurseries can be raised in the same garden so that there will be enough planting material. This system can be of special advantage if the planting material is selected in the month of October or November when the vines will be in full bearing so that cuttings for the nursery can be taken from selected vines. This was tried with success at the Agricultural Research Station, Taliparamba, in the year 1941-42. Milsom [1930] reports that this system of raising nurseries is practised in Malaya.

It is also noted that the plants raised from rooted cuttings or layerings come to flower earlier than the ordinary cuttings, since they get one year's growth in the nursery. This method can be adopted with advantage on a large scale in all the

pepper-growing tracts. There is not much difficulty and the only condition necessary is that there should be facilities for copious watering and provision for adequate shade during the summer months. Cuttings from selected high yielding individual vines may be planted in small nurseries so that they can be planted in selected portions of the field and the performance of the offspring can be tested and verified.

#### CULTURAL METHODS

There is wide variation in the methods of cultivation adopted in the different pepper-growing tracts and they may be roughly classified as follows :

- (1) The Malabar and South Kanara system.
- (2) The Travancore system.
- (3) The North Kanara and Mysore system.
- (4) The Coorg system.

##### *The Malabar and South Kanara system*

(1) Virgin jungle lands are selected and cleared of all undergrowth trees and stumps of dead trees. Pits  $1\frac{1}{2} \times 1\frac{1}{2} \times 1\frac{1}{2}$  feet are dug in rows, the spacing between adjacent pits varying from 8 to 12 feet according to the fertility of the land. In South Kanara 1,000 vines are planted in three acres. The pits are then filled with loose jungle earth and leaf mould. With the advent of the first rains in May or June *Murukku* (*Erythrina indica*) standards, raised from seeds are cut and planted. The method of raising *Murukku* standards is described later in this report under the heading 'Standards'. Within a fortnight these standards strike roots and get themselves established. When the weather conditions are favourable and the monsoon sets in, pepper cuttings are planted near the base of these standards. Usually five cuttings 2 to  $2\frac{1}{2}$  feet long are planted to each standard. These cuttings are planted fan-wise either on the northern or eastern side a little away from the standard and not all in one pit. The southern aspects are always avoided as the afternoon sun in summer months may kill the plants outright or cause 'sun burn'. The soil around the planted cuttings is pressed hard and made sloping away from the standard to prevent rain-water stagnating. The portions of the cuttings above ground are pressed close to the standard and tied. Mulch is provided by putting grass or small twigs round the planted cuttings. The tying of the growing cuttings is attended to periodically, keeping pace with the growth of the vines. In the first year they grow to a height of 4 to 5 feet.

During the first year two diggings and weedings are given to the whole area, one in July after the commencement of the South-west monsoon and the other in November, soon after the North-east monsoon. *Lantana* is a troublesome weed in newly planted pepper plantations in hill slopes and these have to be removed, root and branch.

##### *Mulching*

To protect the young pepper plants from the heat of the sun during the summer months a bunch of leafy twigs of *ivul* (*Xylia dolabriformes*) is tied over them in March but removed with the onset of the monsoon. This shading is done for the

first two years and later only those plants which need protection from the sun are shaded. Too much exposure to sun certainly affects the vines adversely. During the second year practically the same cultural operations are repeated but in the third year besides these operations, the side branches of the standards are pruned and trained to grow straight. Cultural operations during the fourth and fifth years are the same as those in the third year. Lopping of standards is regularly done from the fifth year onwards to regulate shade.

### *Filling up gaps*

This is an item which has to be attended to regularly during the first two to three years. It is not an uncommon sight to see vines of different ages in the same plantations although the original planting was done at the same time. Such disparities in age are attributable to casualties which have to be replaced at different periods.

### *The Travancore system*

(2) The pure crop system practised in Travancore is different from what obtains in Malabar and South Kanara. Virgin jungle is selected but instead of complete clearing of the jungle growth as practised in Malabar and South Kanara the undergrowth of shrubs and weeds is first cleared and some of the standing trees are utilised as standards. Thinning of standing trees is done to provide some sort of spacing. For this reason trees of various sizes, ages and species are found in typical pepper plantations of Travancore. In this system there is considerable variation in the number of vines planted to the acre. The estimation of yield per vine is also rendered difficult as the vines trained on different standards are of different sizes. The number of cuttings planted under each standard depends on the size of the standard.

### *Planting of cuttings*

A semi-circular pit is dug round the northern and eastern sides of the standard and cuttings of pepper vine varying from 3 to 15 in number depending on the girth of the standards, are planted and the free ends of the vines tied to the standard. During the first two years the plantations receive a good digging in July and weeding and chop-digging in November-December, and afterwards most of the planters do only the 'ring' cultivation. The whole area is weeded but digging is given to the area immediately around the vines. When the land is sloping and the cuttings are planted on a slope below the standard a system of 'crescent terracing' is done to prevent erosion of soil around planted vines.

### *Lowering of the vines*

The operation of 'lowering' the already established vines in the second year after planting is practiced in South and Central Travancore by some growers. In the second year after planting, the young vines are carefully pulled away from the standards and a portion of the aerial growth is buried in a trench made near the standards. This encourages rooting of the buried nodes and gives a bushy growth from the bottom of the vines. But since it is a laborious and costly process it is not widely adopted. It is reported that such lowered vines thrive better and yield more than others.

In North Travancore besides the pure pepper plantation, a system of mixed cropping is adopted. Pepper forms mostly an inter-crop in coconut plantations. Pepper and coconut are planted at the same time, the former occupying the intervening space between the coconut seedlings. Under this condition, pepper is kept on the plantation for 12 to 15 years, by which time the coconut trees come into full bearing, when the vines either perish or deteriorate. Usually standards of *Erythrina indica* are used but unlike the practice in Malabar the cuttings are taken from old grown-up trees and not from seedling trees raised specially for this purpose. In Malabar, seeds of *E. indica* are sown and the seedlings are allowed to grow for three years. They are then cut close to the ground and planted as standards. Standards raised under this system are said to strike roots better than the cuttings taken from grown-up trees.

#### *The North Kanara and Mysore system*

(3) In North Kanara and Mysore, pepper is grown mostly as a subsidiary crop in arecanut gardens along with cardamom and bananas. The arecanut trees form the standards for pepper. The arecanut gardens are situated at the lower slopes of valleys. As natural drainage is defective in such situations, elaborate arrangements are made for drainage. The area of individual gardens varies from 2 to 10 acres but the majority of the holdings are below 5 acres. The owner farmers who live near their gardens personally attend to the cultural operations. The arecanut trees receive manuring regularly. The gardens receive clean cultivation, the weeds are removed and a digging given. In alternate years a heavy application of green leaf mulch to a depth of 2 to 3 feet is given. Cattle manure at the rate of one basketful (25 to 30 lb.) is applied to each tree in the next season. The pepper vines receive the benefit of the attention bestowed on the areca palms on which they are trained. In most gardens bananas are grown and those which grow to a height of 18 to 20 feet more or less shut out direct sunlight from the ground. While this is good for cardamoms, it is of very doubtful value to pepper. It is found that under such shady conditions more spikes are formed at the top than at the lower reaches of the vines. If proper attention is paid to the selection and propagation of good varieties and also to the regulation of shade, the yield of pepper can, no doubt, be increased. In no other tract does pepper receive the benefit of such regular and systematic manuring.

No special cultural operations are done to the pepper except the tying of the vines to the standards to assist their climbing. This operation is carried out regularly either in May just before the monsoon sets in or during the break of the monsoon in September. The leaf sheaths of areca palms are torn into strips and these are used for tying the vines to the areca stem. Unlike *E. indica* and other trees with coarse bark, the areca palm does not offer a good hold for the aerial climbing roots of pepper. For this reason this defect is largely made up by more elaborate system of tying of growing shoots. About 20 strings being tied to a full grown vine. The vegetative runners arising from the base of the vines are layered and trained on the standards. By this system the areca stem is covered by the vine all round. This practice is well worth introduction into other pepper-growing tracts.

*The Coorg sysime*

(4) Pepper is generally planted as a subsidiary crop in the coffee plantations and trained on the shade trees. The common shade trees in coffee plantations are (1) silver oak (*Grevillia robusta*), (2) thari (*Terminalia bellerica*), (3) mathi (*Terminalia tomentosa*), (4) bilwara (*Albizia odoratissima*) and honne (*Pterocarpus marsupium*). Pepper is not grown in all coffee estates, but it is grown largely in South Coorg, round Polibetta, Thithmathi, Ponnampet, Ammathi and Sidapur. The average number of vines per acre varies considerably and it may be anything from 10 to 40. It is not possible to correctly estimate the number of vines per acre in a coffee-cum-pepper plantation. Usually three to five cuttings of 2 to 2½ feet in length are planted in July to a standard either on the east or northern side. As in other tracts the western sun is usually avoided. Some planters use rooted cuttings and plant them with a ball of earth. Once the vines are established, they do not receive any special attention or cultivation, but they receive the benefit of the periodic manuring, weeding and other cultural operations given to the coffee. The vines are found thriving well and grew to a height of 30 feet on some of the shade trees. The yield of vine in full bearing varies considerably from 5 lb. to 25 lb. per vine depending on seasonal factors. There is practically no recurring expenditure except the cost of harvesting.

## STANDARDS

Pepper being a climbing plant, supports or 'standards' as they are called, are provided prior to the planting of vines. These 'standards' besides serving as supports provide 'shade' for the pepper plants. In South India live standards are as a rule favoured, while in the Malay Archipelago it is reported that 'dead' standards are provided [Milsum, 1930].

*Raising of murukku (Erythrina indica) standards in Malabar and South Kanara*

The seeds of *E. indica* are sown along with hill paddy *pinam* cultivation and after the harvest of the paddy crop the *Erythrina* seedlings are allowed to grow undisturbed. When the plants have grown to about 5 to 7 feet in height and 6 to 8 inches in girth they are cut close to the ground and stacked horizontally in shade for 2 to 3 weeks. The stumps are then removed and kept in a slanting position at about an angle of 60° for about a month when new shoots will be produced and roots begin to develop at the cut ends. They are then ready for planting and are planted in pits of 1½ × 1½ × 1½ feet, 8 to 12 feet apart depending on the fertility of the soil. Three weeks later when the standards have established themselves, pepper cuttings are planted at the base of the standards and tied to them. In Travancore, branches of *Erythrina indica* are cut from old grown up trees and planted as standards and not grown specially from seeds as is practised in Malabar and South Kanara. It is reported that in Travancore the standards of *E. indica* are of much shorter duration than in Malabar and this is probably due to the difference in the method of raising the standards. Though *E. indica* standards have certain defects such as having shorter life than many of the other standards and of shedding its leaves in the hot weather, it is still one of the most common standards for pepper. The following are some of the points in its favour: (1) It can be easily propagated and is a quick

growing plant ; (2) it is a straight growing plant without many side branches ; (3) the aerial climbing roots of pepper get well established in the early stage as the bark of *E. indica* is rough and secretes a sticky fluid which enables the roots to get a firm hold ; (4) it can stand the annual lopping without serious deleterious effects ; (5) it is a leguminous plant and enriches the nitrogen content of the soil.

Besides *E. indica* the most common standards used are *karagan* (*Garuga pinnata*), *ambazham* (*Spondias mangifera*), *thani* (*Terminalia belirica*), *alam* (*Carega arborea*), *maruthi* (*Terminalia paniculata*), *venga* (*Pterocarpus marsupium*), mango (*Mangifera indica*), teak (*Tectona grandis*) and silver oak (*Grevillea robusta*).

#### *Lopping of standards*

The idea of lopping is to regulate the shade and allow more sunlight and air to the vines at a period when they need them most. This is usually done in June-July with the commencement of the rains for all standards except *E. indica*, which is generally lopped in March which is a dry month and the plant sheds all its leaves. *E. indica* is not lopped during the rainy season, i.e., June-July, as the cut ends are reported to harbour wound parasites which cause 'die back'. Lopping of standards is usually done in alternate years, but the wisdom of this practice is not clear. It would be desirable to study this question in detail at an experimental station.

#### *The effect of standards on the vine*

No experiment has so far been done on this aspect and therefore it is difficult to form any definite opinion. Pepper being shallow rooted, the root system of deep rooted trees would not compete with pepper for sub-soil nutrition. The effect of standards on the vine, if any, would appear, however, to be more mechanical than physiological, in that they serve as support, and the facility with which the adventitious roots of the pepper plant are able to grip the bark is a factor which may vary with different species of trees and with different varieties of vines. There is, however, reason to believe that some standards deplete the food ingredients from the soil in the feeding region of the vines to a greater extent than others and this is another factor which varies with standards. Observations made during the survey show that vines growing on dying and dead standards thrive well and yield better crops. The experience of growers may be summarised in the following words : "A good standard means a good vine."

#### *Dead standards*

Milsum [1930] states that in China and Malay Archipeiage the pepper vine is trained on dead standards and the yield is reported to be good. An attempt was made at the Agricultural Research Station, Taliparamba, to find out if the vines could be successfully trained on dead standards. Vines were trained on dead standards of irul (*Xylia dolabriformis*). The standards decayed before the vines reached the effective bearing period and the idea was given up.

### MANURING

#### *Local practices*

This aspect has not received much attention so far. Some cultivators apply cattle manure and leaf mould and their experience is that it pays to manure the vines as the yield is increased. But, as a rule, cultivators do not apply any other

manure except the leaves and twigs of lopped branches of the standards once a year. The organic matter thus applied is too meagre to meet the requirements of the vines and while the crop is able to maintain itself in virgin soil for some years, sooner or later the crop deteriorates, the yield gradually going down year after year. Cattle manure is not used not due so much to want of knowledge of the beneficial effects of the manuring as the non-availability of cattle manure. What little cattle manure the cultivator has, he applies to the paddy crop under a mistaken notion that it gives a quick return. During the survey it was noticed that some ryots use even the loppings from the standards as green manure to the paddy crop.

#### *Manurial experiments*

Very few experiments on the manurial requirements of this crop have been done and of these, two which were conducted at the Agricultural Research Station, Taliparamba, may be mentioned. The first experiment was for the purpose of comparing the relative efficacy of organic manures.

TABLE IV

*Results of manurial experiments conducted at the Agricultural Research Station, Taliparamba, during the years 1918 to 1928*

Treatments	Average yield of green pepper in mm. per 100 vines	Average yield taking control as 100
1 Fish guano $\frac{1}{2}$ lb. per vine . . . . .	102.6	172.7
2 Fish guano $\frac{1}{2}$ lb. lime $\frac{1}{2}$ mm. 20 lb. leaf mould in alternate years .	91.3	153.5
3 Green leaf mulching . . . . .	86.7	146.0
4 Leaf mould 20 lb. per vine . . . . .	80.8	136.0
5 Lime $\frac{1}{2}$ mm. plus 20 lb. leaf mould per vine . . . . .	62.2	109.8
6 Control (no manure) . . . . .	59.4	100.0

NOTE. 1 mm. of green pepper =  $2\frac{1}{2}$  lb. and one mm. on drying will give 1 lb. (approximately)

#### *Results*

Fish manure gave the highest yield followed by (1) Fish guano and leaf mould, (2) leaf mulching, (3) leaf mould. It is interesting to note that mere leaf mulching of the soil increases the yield.

The second experiment carried out by the Government Agricultural Chemist at the Agricultural Research Station, Taliparamba, attempted to find out the manurial requirements of pepper. The following Table gives the results of the experiment.

TABLE V

*Showing the results of manurial experiments*

	Yield of green pepper on original population basis (average of 10 years)			
	Limed series		Unlimed series	
	Tolas per vine	Percentage increase	Tolas per vine	Percentage increase
No manure . . . . .	5.7	..	2.2	..
Nitrogen (sodium nitrate) . . . . .	8.3	45.6	4.9	122.7
Nitrogen + potassium sulphate . . . . .	15.5	172.0	7.6	245.5
Nitrogen + superphosphate . . . . .	17.0	138.3	9.0	309.1
Potash + phosphate . . . . .	15.8	177.2	6.1	177.3
Nitrogen + potash + phosphate . . . . .	8.9	56.1	6.3	181.9

N= $\frac{1}{4}$  lb. sodium nitrate per vineK= $\frac{1}{4}$  lb. potassium sulphate per vineP= $\frac{1}{4}$  lb. super phosphate per vine

The general mean of the limed series is nearly double that of the unlimed series, the beneficial effect of the lime is clear. All the manures have responded well in both limed and unlimed series, the maximum yield being with nitrogen *plus* phosphoric acid in the presence of lime, closely followed with narrow limits by K P, N. K and N K P, and with the least response from nitrogen only. The results indicate that leaf mould (20 lb.) *plus* fish guano ( $\frac{1}{4}$  lb.) per vine as well as artificial (sodium nitrate  $\frac{1}{4}$  lb., potassium sulphate  $\frac{1}{4}$  lb., super  $\frac{1}{4}$  lb.) answered the requirements of pepper generally.

Both these experiments indicate the need of application of calcium and it is known the Malabar soils are notoriously deficient in this mineral. In assessing the above results of this experiment, the lay out and the selection of planting material for the various treatments, left much to be desired due to the following factors: (1) The planting material was **taken** from different vines: (2) the plot selected was slopy and had a southern aspect which has a deleterious effect on the crop. There is scope for laying out a correctly-planned experiment with planting material of the same age and selected from uniformly high-yielding vines and in a block of land of uniform fertility. In this connexion it may be mentioned that the best method of obtaining uniform planting material for experiments of this kind is as follows. A large number of cuttings cut from a single high-yielding vine can be first planted in a nursery, allowed to root and then transplanted in the experimental area. This will give a more or less uniform stand.

TABLE VI

*Results of the manurial experiments conducted by the Agricultural Department, Travancore, at the Agricultural Farm, Konni*

Year	Yield of green pepper in lb.	
	Manured	Control
1929 . . . . .	16	13
1930 . . . . .	36	25
1931 . . . . .	30	28
1932 . . . . .	40	28
1933 . . . . .	50	32
1934 . . . . .	52	40

Manure applied was a mixture of 10 lb. leaf mould, 3 oz. ammonium sulphate 10 oz. super-phosphate. Control received only 10 lb. leaf mould. The results indicate that nitrogen *plus* phosphoric acid increased the yield.

Milsom [1930] reports the use of burnt earth as a manure for pepper was commonly practised in the Straits Settlements in the past and is considered of primary importance in the cultivation of this crop in Sarawak. Bushes, branches of trees and other vegetable matter are collected and heaped and partially sun-dried. Soil is then added until the whole forms a large heap. The wood is then ignited and the heap allowed to burn. The resulting burnt earth and wood ashes are thus applied to the base of the pepper plant several times during the year.

#### AFTER CULTIVATION

##### *Digging*

Two diggings and weedings are given, the first in June to July soon after the commencement of the south-west monsoon. The second in the month of October to November soon after the north-east monsoon. The object of the first digging is to conserve the rain water and minimize surface wash. The object of the second digging is to keep the soil loose with a view to conserve the soil moisture. Most cultivators do these operations regularly year after year. It is to be considered whether the diggings of the whole area of the garden is necessary. The roots of the pepper plant do not appear to go beyond  $2\frac{1}{2}$  to 3 feet. Hence it looks as if a scraping to remove the weeds and a light digging round the plants, without damaging the root system will serve the purpose. In Travancore most of the planters give only a clean weeding to the whole area and practise 'ring cultivation' round the plants. The yield in Travancore does not seem to be less, in any way than the yield obtained in Malabar. Till experiments on these aspects are conducted it is not possible to advocate any system of inter-cultivation.

In Travancore some planters make mounds of broken stone round the base of the pepper vine instead of terracing. The weeds are removed and wherever cattle manure is available it is applied with green leaf near the base of the vines.

### *Tying of vines*

This operation is done regularly during the first three to four years, but when once the vines establish themselves on the standards, its continuance becomes unnecessary especially for the vines growing on *Erythrina* standards. This is due to the fact that the production of vegetative branches is reduced and more flowering branches are formed. The fibrous bark of a common creeper called *choula* (*Helicteres isora*) found in the scrub jungles of Malabar is commonly used for tying the vines, but sometimes small sized coir ropes are also used.

In Travancore some of the varieties under cultivation appear to be better climbers than the common varieties of Malabar and the tying of vines is done only for the first three years but when once they get themselves established on the standards, no further tying is done. In Malabar this operation is a regular item every year.

### *Regulation of shade*

The pepper plant requires shade as too much exposure of the young vines to the hot sun is found to have a deleterious effect. At the same time if the vines do not get sufficient sunshine, the flowering is affected and poor setting results. So the regulation of shade is an important aspect and should be attended to regularly. As a rule the standard which supports the vine provides the necessary shade. While lateral shade is necessary, the top shade during the rainy seasons should not be too heavy and has to be regulated. This is done by judicious lopping of the standards. These standards should be such that they retain the leaves during the hot weather and put forth new leaves with the commencement of the monsoon in June-July. In this way the vines will get enough shade during the hot weather months of March to May, and the lopping, if done soon after monsoon sets in, will provide sufficient sunlight for the flushing and subsequent formation of berries. This is a complicated problem and experiments should be conducted to see the best method of regulating the shade and also to know the optimum shade and light requirements of the pepper plant.

### *Mulching*

This is done regularly in March for all the newly-planted vines for the first 2 to 3 years, but later this practice is adopted in the case of young vines which are too much exposed to the sun. Experiments at the Agricultural Research Station, Taliparamba, show that mere mulching of the soil round the vines has increased the yield of pepper.

## CULTIVATION EXPENSES

According to the Malabar system the initial cost of laying out a garden and planting the vines is rather heavy. The selected site has to be cleared of all weeds, scrub jungle, trees and old stumps. Then pits at the rate of 1,000 per 3 acres have to be dug and standards planted before the planting of vines. The average cost per acre comes to Rs. 160 to Rs. 170 (as per details furnished in Table VII below).

*Recurring expenses*

Unlike other garden crops on the West Coast, pepper requires continuous attention and care. The pepper garden should be cultivated regularly every year as otherwise the land will be outgrown with weeds and jungle growth. Besides the yield being reduced, such a course would ruin the plantation permanently. So whether the cultivator gets a good crop or a fair price for his produce, he cannot afford to neglect his gardens. So long as there was a good price for pepper every thing went on well, but with the depression during the years 1931-1941 most of the ryots were in difficulties. During this period some of the gardens went out of cultivation and became derelict. When the price of pepper ruled high during 1925-1931 it gave a great impetus to pepper cultivators and people brought new lands under cultivation. In the scramble for land all kinds of land were selected, without due regard to their suitability. Pepper prospecting received a rude shock when the price of pepper suddenly dropped in 1931 and not only did expansion on any large scale stop, but also some of the newly-planted gardens were abandoned.

TABLE VII

*Statement showing cost of raising 1,000 vines in 3 acres in Malabar and South Kanara*

	Rs. as. p.
<i>First year</i>	
1 Clearing of old stumps—200 men at 8 annas . . . . .	100 0 0
2 Transporting 1,000 standards and planting—100 men at 8 annas . . . . .	50 0 0
3 Wages for coiling and cutting the vines—20 men at 8 annas . . . . .	10 0 0
4 Planting pepper cuttings—20 men at 8 annas . . . . .	10 0 0
5 First digging—100 men at 8 annas . . . . .	50 0 0
6 Second digging—50 men at 8 annas . . . . .	25 0 0
7 Tying of vines—10 men at 8 annas . . . . .	5 0 0
8 Mulching—25 men at 8 annas . . . . .	12 8 0
Total . . . . .	262 8 0
<i>Second year</i>	
1 Cleaning and digging—60 men at 8 annas . . . . .	30 0 0
2 Weeding—30 men at 8 annas . . . . .	15 0 0
3 Tying of vines—10 men at 8 annas . . . . .	5 0 0
4 Filling up gaps—20 men at 8 annas . . . . .	10 0 0
Total . . . . .	60 0 0

March, 1949 ]

SURVEY OF POLLU AND ROOT DISEASES

*Third year*

Rs. as. p.

Same as second year *plus* 10 men for lopping the side branches of standards (item 4 excepted).

55 0 0

*Fourth year*

Same as third year . . . . .

55 0 0

*Fifth year*

Same as second year (item 4 excepted) *plus* 30 men for lopping branches of the standards.

65 0 0

First year . 262 8 0

Second year . 60 0 0

Third year . 55 0 0

Fourth year . 55 0 0

Fifth year . 65 0 0

Grand total . 497 8 0

Cost per year is Rs. 166 to Rs. 170 per acre

*Recurring expenses*

Rs. as. p.

The cost of recurring expenses for 3 acres is . . . . .

65 0 0

The cost of recurring expenses for 1 acre . . . . .

22 0 0

*Cost of bringing one acre of land of pepper under cultivation in Travancore  
(pure pepper plantations)*

1 Clearing undergrowth and over-crowded trees and burning . . . . . 20 0 0

2 Digging pits  $1\frac{1}{2}$  ft.  $\times$   $1\frac{1}{2}$  ft.  $\times$   $1\frac{1}{2}$  ft. at Rs. 3-2-0 per 100 . . . . . 9 8 0

3 Cost of cuttings . . . . . 10 0 0

4 Planting, 20 coolies . . . . . 10 0 0

5 Filling up gaps, 5 men . . . . . 2 8 0

6 Weeding, 20 women . . . . . 5 0 0

7 Mulching and shading . . . . . 13 0 0

Total . 70 0 0

*Second year*

1 Digging 10 ft. round the vine and levelling square and 1½ ft. deep . . . . .	75 0 0
2 Lowering of vines, 20 men . . . . .	10 0 0
3 Weeding, 40 women . . . . .	10 0 0
4 Lopping . . . . .	5 0 0
5 Mulching and shading . . . . .	13 0 0
6 Filling up gaps . . . . .	2 8 0
<hr/>	
Total . . . . .	115 8 0
<hr/>	

*Third year*

1 Weeding, 40 women . . . . .	10 0 0
2 Digging round the vines, 30 men . . . . .	15 0 0
3 Lopping, 10 men . . . . .	5 0 0
4 Mulching, 20 men . . . . .	10 0 0
<hr/>	
Total . . . . .	40 0 0
<hr/>	

*Fourth and fifth years*

Same as third year . . . . .	80 0 0
<hr/>	
First year . . . . .	70 0 0
Second year . . . . .	115 8 0
Third year . . . . .	40 0 0
Fourth year . . . . .	40 0 0
Fifth year . . . . .	40 0 0
<hr/>	
Grand total . . . . .	305 8 0
<hr/>	

*Comparative statement showing the cost of cultivation of one acre (pepper) during  
1938-39 and 1943-44*

	1938-39	1943-44
	Rs. as. p.	Rs. as. p.
1 Digging round vines in May to June—10 vines for coolie, 30 coolies per acre	7 8 0	22 8 0
2 Mulching in October-November, 20 vines per man . . . . .	3 12 0	11 4 0
3 Weedings (two) at the rate of 20 women for one weeding . . . . .	5 0 0	10 0 0
4 Cost of harvesting and drying produce from one acre . . . . .	13 8 0	39 0 0
5 Lopping of branches . . . . .	2 4 0	6 0 0
Total . . . . .	32 0 0	89 4 0
		or
		90 0 0

NOTE.—Rate of wages in 1938-39.—A man 4 annas and a woman coolie 2 annas.  
Rate of wages in 1943-44.—A man 12 annas and a woman coolie 4 annas.  
Number of vines per acre assumed to be 300.

### DISEASES AND PESTS

#### *Diseases of pepper in other countries*

The diseases of pepper that have been recorded are not many and the following are some of them :

(1) *Black fruit*, caused by *Cephaleuros mycoidea* is a very serious disease of pepper in Sarawak. "The fruiting spikes set normally but after a time, the berries at the free end turn black, shrivel and some fall off. At this state the remainder of the practically ripe berries will show small black spots, which under a hand lens, show minute golden tufts typical of *Cephaleuros mycoidea*. The disease progresses and the berries about the middle of the spike shrivel and turn black. In the final stages the whole of the berries on the spike is involved, most fall to the ground but usually a few mummified berries still remain attached to the blackened spikes." [Sharples, 1922].

(2) Another disease of pepper has been recorded from Sarawak and has also been noticed in Singapore. "The pepper spike while still green and unripe, show at first a yellowing on some of the fruits. These instead of becoming deeper green, eventually, become dry and quite black, the whole interior becoming black and powdery. Then on the outside of the pepper appear small black processes the fruit of the fungus. As a rule only a few of the fruits on the spike are affected and these generally in the middle of the spike. The fruit spike is thus spoiled and generally falls off before it is fit together." This is said to be caused by a species of *Colletotrichum* which has been named by Mr. Massee as *Colletotrichum necator*.

(3) Pepper (*Piper nigrum*) suffered from an obscure die-back of the branches in Atjeh and it was affected by a disturbance in which the fruit bearing shoots were replaced without apparent cause by those producing nothing but leaves [Leafnans, 1933].

*The Phytophthora foot-rot of pepper (Piper nigrum) in the Dutch East Indies*

(4) Since 1928 foot-rot of pepper has assumed major importance in the most of the cultivation centres in Sumatra, Java and Borneo. In some districts the ravages of the disease have necessitated the abandonment of the crop. 'Infection usually begins on the stems at a height of up to 30 c.m. from the base, and on non-suberized stems the diseased cortex rapidly turns from dark watery green to black, but no external symptoms are apparent on cork covered bark. The soft parenchymatous tissues of the cortex and medullary rays quickly decay, while the xylem remains intact, apart from a slight brownish discolouration. The affected bark often peels off and the central cylinder splits into a bundle of loose xylem vessels due to the rotting of the connecting tissues. The leaves turn yellow, wilt and drop, or in dry hot weather they may blacken and adhere to the plants. Most of the roots of the wilting plants are still normal but foot-rot symptoms begin at the base and progress towards the root tips. During the period of active spread of the disease, somewhat inconspicuous greyish-brown spots up to 5 cm. in diameter are formed near the tips and margins of the lower leaves, and the lesions are surrounded by a zone, 3 to 5 m.m. in width of water, dark green tissues from the under side of which drops of a yellowish fluid are exuded. Both the leaf surfaces of pepper are readily infected by the mycelium and conidia of the *Phytophthora*, the zoospores of which can only attack the undersides. The typical lesions develop in two to three days, and during the night conidia are formed in profusion on the lower leaf surfaces. Diseased leaves are shed before the fungus reached the petioles.

The chief sources of infection by *P. palmivora* var. *piperis* are contaminated water, soil and diseased plant refuse. Transport by water seems to be the chief mode of conveyance of the fungus, which is almost destructive in well cultivated gardens. Experiments have shown that the foot-rot of pepper may be partially controlled by fortnightly applications of 1 per cent Bordeaux mixture. In order to minimize the risk of soil infection a net work of shallow drain trenches should be dug, with catch pits at intervals, to prevent the rain water from running off over the soil surface. When infection occurs in one of the squares, isolated by the trenches, the soil and the diseased plants should be watered with 5 to 10 litres of 1 per cent copper sulphate solution, per square meter and weeding should be temporarily discontinued to prevent the transmission of the fungus by implements or by labourers' feet or by similar means' [Muller, H.R.A. 1937].

*Anthraco-nose of black pepper (Piper nigrum)*

(5) Anthracnose is a minor disease of black pepper. It attacks the foliage and produces dead areas which interfere with the function of leaves. In the early stage of the disease the lesions are small and dark grey, irregular in size and shape, and have a distinct border. In the advanced stage the lesions enlarge and merge together forming large dead areas. The mycelium of the fungus is septate, coarse hyaline and granular in contents, either simple or branched and  $15.7 \times 6.1 \mu$ . The conidiophores are simple, hyaline, granular, non-septate and  $98.0 \times 4.3 \mu$ . Each conidiophore produces 2 to 6 or more conidia at the tip. The conidia are thin-walled, rounded at the end, oblong, elliptical, hyaline with granular contents,

easily detached from the conidiophores and  $15.7 \times 5.2 \mu$ . In masses the spores are pinkish but become dark or almost black with age. The fungus is referred to the species *Glomerella cingulata*, S. and V.S., but it produces only the imperfect stage. The spores of the fungus are disseminated perhaps by wind, rain or water passing over the infected areas of the leaves. Under climatic conditions in the Philippines, the fungus can remain in the form of dormant mycelium in the infected host tissues during dry weather. Rainy days favour spore germination and penetration of the host. Young and tender leaves and sun-scalded and sun-burned areas are readily infected by the causal fungus. The disease may be controlled, by collecting and burning the infected leaves' [Vinukatanandara *et al*, 1930].

*Diseases of pepper in India—(1) Root disease or 'wilt' diseases*

From the official records it can be gathered that the attention of the Madras Agricultural Department was directed towards a study of the pepper crop consequent on alarming and urgent appeals by the South Wynaad Planters' Association to the Government for help in combating a serious 'wilt' disease which was taking a heavy toll in their plantations as early as 1902. In response to this appeal, Dr C. A. Barber, the then Government Botanist, visited the areas. His inspection revealed that in these areas the practice of heaping up soil to form a mound round the base of the vines was prevalent. This induced formation of superficial fibrous roots which permeated the soil in the mound in addition to the normal root system. Barber made the interesting observation that in all diseased vines the surface roots were the first to rot and perish while they remained healthy and persistent in the normal vines. In 1904 Dr E. J. Butler, the Imperial Mycologist, made a tour of inspection of the affected areas, where he found several plantations virtually depleted of vines by the wilt disease. He found that vines in exposed situations more readily succumbed to disease than those under shady conditions. He arrived at the conclusion that *Nectria* sp. was responsible for the disease. Perithecia of this fungus were found in large numbers at the base of the stem of the diseased vines. He compared this problem to the wilt of pigeon pea (*Cajanus cajan*) caused by *Fusarium udum*. At that time perithecia of *Neocosmospora vasinfecta* had been observed on the stem of diseased pigeon pea plants and this fungus was presumed to represent the perfect stage of the organism causing the wilt of the pigeon pea.

*Stump rot*

(2) Butler further found evidences of the existence of stump rot in pepper in Mysore caused by *Rosellinia bunodes*. Diseased patches were observed in some of the plantations where, besides the pepper vines, the standard trees and a variety of undergrowth had been killed by this fungus. In pepper the death of the vines was rather sudden; the leaves turned yellow and soon the vines became defoliated and the stem dried up.

*'Pollu'*

(3) Since then, no sustained investigation has been conducted on this problem and though the disease has made a sporadic appearance in later years it has not been reported to have assumed dangerous proportions. But about the year 1918 the pepper crop again attracted the attention of the plant pathologist, but this

time it was another disease locally known as *pollu* (meaning hollow or light). On account of this disease, a varying percentage of the yield of vines was found to consist of hollow or light berries. The problem was first investigated by the Government Entomologist, Madras, and in later years jointly by the Government Mycologist and the Government Entomologist. The results of these investigations were published from time to time (1926, 1939). The conclusions arrived at, show that *pollu* (hollow berry) is attributable to three main causes, viz., (1) A fungus (*Collectotrichum* sp.), (2) A flea beetle (*Logitarsus nigripennis*), (3) Premature spike shedding. Of these *Collectotrichum* sp. has been found to be responsible for causing shrinkage and drying up of individual berries and to a small extent infection of the stalks of spikes. Further the same fungus causes spots in leaves and sometimes infect the stem causing the death of young vines or fruiting branches.

The second cause of *pollu* is insect damage. Two insects have been found responsible for damage to berries, a flea beetle commonly known as *pollu* beetle (*L. nigripennis*) and a gall-fly. The latter is only a minor pest but the former causes serious damage. By far the major portion of what is known as *pollu* in the trade is caused by premature shedding of spikes. The cause of spike fall has not been determined but experienced growers attribute it to either paucity or excess of rainfall. The following Table gives data collected in 1932 at the Agricultural Research Station, Taliparamba, which bring out the relative importance of spike fall, insect and fungus attack on the causation of loss by *pollu* [Thomas and Krishna Menon, 1939].

TABLE VIII

*Showing the relative importance of spike fall, fungus and insect attack*

Variety	Percentage of loss by spike fall	Percentage of loss by fungus	Percentage of loss by insects
1 Balamcolta . . . . .	46.3	5.6	9.2
2 Kallunalli . . . . .	37.9	6.1	13.7

*Diseases observed during the survey—root-rot*

Root-rot (wilt) was in evidence to a small extent in all the tracts visited. In no place was the disease found to be prevalent in an alarming extent or intensity. Information gathered from the growers goes to show that this disease is not of the same intensity in all years. It usually exists in a sporadic form, involving 2 to 10 per cent of the vines of the plantations. Owing to the vicissitudes through which the industry has passed, the fluctuations in the price of pepper and consequent neglect of the gardens during slump seasons, the low percentage of mortality among the vines has seldom upset the equanimity of the growers. But it is reported that during certain years a much higher percentage of deaths occurs but the losses never attained the level it reached in the early years of this century. Among the tracts surveyed, a higher incidence was still in evidence in Wynad, Coorg and Travancore.

The dead and dying vines observed in different tracts were carefully examined. In all cases fungi were noticed in the tissues of the roots and base of the stems. Small bits of tissue from the interior of the roots and stems of the dying vines were transferred to agar media and several fungi have been isolated. Two fungi were constant factors. These are *Diplodia* sp. and *Rhizoctonia solani*.

TABLE IX  
*The fungi isolated from different localities*

Serial number and tract	Locality	Portions from which obtained	Fungus	Percentage of incidence
1. Wynaad	Chundale	Roots	{ 1 <i>Diplodia</i> sp. 2 <i>Rhizoctonia solani</i> 3 <i>Fusarium</i> .	5—10
2. do.	Kalpetta	do.	{ 1 <i>Diplodia</i> sp. 2 <i>R. solani</i> . 3 <i>Fusarium</i>	5
3. Travancore	Kanjirapally	do.	{ 1 <i>Diplodia</i> sp. 2 <i>R. solani</i>	5
4. do.	Todupuzha	do.	{ 1 <i>Diplodia</i> sp. 2 <i>R. solani</i> 3 <i>Pythium</i> sp.	5—10
5. S. Malabar	Manarghat	do.	{ 1 <i>Diplodia</i> sp. 2 <i>R. solani</i>	2
6. do.	Chalasseri	do.	1 <i>Diplodia</i> sp.	2
7. Cochin State	Kunnamkulam	do.	1 <i>Diplodia</i> sp.	2
8. Mysore	Balehonnur	do.	{ 1 <i>Diplodia</i> sp. 2 <i>Fusarium</i>	2
9. do.	Telagupa	do.	1 <i>Diplodia</i> sp.	2
10. North Kanara	Malvalli	do.	1 <i>Diplodia</i> sp.	2
11. Coorg	Pollibetta	do.	{ 1 <i>Diplodia</i> sp. 2 <i>R. solani</i> 3 <i>Bacteria</i>	5—10
12. do.	Ammatti	do.	1 <i>Diplodia</i> sp.	5

The constancy with which *Diplodia* sp. and *Rhizoctonia solani* appear among the various isolations leads one to suspect that these might have a leading role to the causation of the disease. Species of *Diplodia* and *Botryodiplodia* have a very wide distribution in the tropical belt and have a reputation of causing root-rots of a number of perennial plantation crops like citrus, cacao, tea, coffee and para rubber. Though it is not possible to assert anything without experimental proof, it may be assumed from the frequency with which this fungus was isolated from all over the pepper tracts, that it may be one of the parasites or at least assumes the role of a parasite under certain predisposing conditions.

Next in frequency of occurrence was *Rhizoctonia solani*. This fungus was isolated from areas as far apart as South Travancore and Wynaad (Malabar). This organism is also known to attack roots of a variety of crop plants and cause 'damping off' and wilt diseases.

*Colletotrichum* sp. was also isolated from diseased vines (stem) obtained from Chundale (Wynaad). This fungus is already known to infect the stem, leaves, spikes and berries of pepper.

From Travancore one isolation of *Pythium* sp. has been obtained, yet it is an important record of a notorious genus of root-rotting fungi. Outside India, *Phytophthora* has been found to be causing wilt of pepper in Malaya. It is equally possible that *Pythium* is also responsible for wilts, and the warm humid climatic conditions of the pepper areas are eminently suited for this genus.

Though it is not possible to fix the responsibility for the causation of 'wilt' on any one of these it is just possible that each one of these is capable of producing root rot and wilt of pepper, and this is a point which required further investigation.

Properly controlled infection experiments alone can decide the question. Besides these fungi, in Coorg an insect was noticed on most of the dead vines and it is possible that this also may be one of the agents causing death of vines. Tunnels are made in the stem and pupae present inside these.

### *Pollu*

During the survey it was noticed that wherever mature spikes were present only a low percentage of 'fungus pollu' occurred. Collections of these diseased spikes from different localities were examined and in all cases the same fungus was observed. All isolations have produced growths of *Colletotrichum* in culture. It can be seen that this fungus enjoys a very wide distribution all over the pepper growing tracts of South India.

The fungus infects berries. The affected berries show in the early stages water-soaked brown sunken areas, and gradually the discolouration spreads over the entire berry and to a few berries on either side. Usually the discoloured berries occur in groups of two to five in number. In later stages the berries may split and acervuli of the fungus develop on the surface. Specimens obtained from Dubary Estate,

Pollibetta, Coorg, exhibited a greater amount of damage caused by the fungus. The spikes are infected at the distal ends exhibiting blackening and drying. The injury extends towards the base and involves some of the berries also. Sometimes half the spike may be involved.

During the time of the visit, viz., September-October, the infection had just commenced in these areas and it was not possible to estimate the extent of damage. But the occurrence of the same fungus all over the pepper growing areas suggests that it is a source of potential danger. Information elicited from the growers also show that the intensity of *pollu* is not of the same order in all years but varies very much from season to season. It was also reported that the loss from *pollu* was most frequent in a distinct contiguous tract extending from North Malabar to South Kanara. In this tract a greater percentage of loss is due to premature spike shedding. In some years it is reported that *pollu* cause a loss of nearly 30 per cent of the produce. It must also be remembered that *Balamcottu* is the major variety under cultivation in this tract. Records of the study of the *pollu* problem made by the Madras Agricultural Department (1926-1939) have shown that spike fall is heavier in *Balamcottu* and this may be one of the reasons for the heavier incidence of *pollu* in this tract. Spike shedding like boll shedding in cotton and button shedding in coconuts may be largely caused by disturbances in water relations of the pepper plant, but is to some extent due to the parasitic organism, *Colletotrichum* sp. affecting the stalk of the spike. This is an aspect of the problem which has to be investigated by suitable experimentation.

TABLE X

*Showing the distribution of Colletotrichum sp.*

Number	Tract	Locality	Parts of plants found affected
1	South Kanara	Kanhangad	Leaf
2	Malabar	Taliparamba	Leaf and berries
3	do.	Payyanur	do.
4	do.	Iritty	do.
5	do.	Mattanur	Leaf
6	do.	Wynaad	do.
7	do.	Kalpetta	do.
8	do.	Manantoddy	do.
9	do.	Manarghat	do.
10	do.	Chalasseri	do.
11	Cochin State	Kunhamkulam	Leaf and berries
12	do.	Vaniampara	Leaf
13	do.	Ollukara	Leaf and berries
14	Mysore	Balehonnur	
15	do.	Talagupa	Leaf
16	do.	Sagar	do.
17	North Kanara	Sirsi	do.
18	Coorg	Sidapur	do.
19	do.	Ammatti	do.
20	do.	Pollibetta (Dubary Estate)	Leaf berries and tip of spikes

TABLE XI

*Showing the effect of the aspect of hill slope on the incidence of pollu. Chirakkal Taluk*

Situation	Percentage of diseased tips	Number of berries		Percentage of <i>Pollu</i>	Weight of berries		Variety of pepper
		Healthy	<i>Pollu</i>		Healthy	<i>Pollu</i>	
A. Northern slope	18	1,426	501	26	9½	1½	Balamcotta
B. do.	14	1,519	564	27	10½	2½	do.
C. do.	14	1,684	528	24	11	2½	do.
D. Southern slope	6	2,082	131	6	21	½	do.
E. do.	2	2,021	63	3	21	¼	do.

It will be seen from the above Table that gardens A, B and C which are situated on the northern slopes show a high percentage of *pollu* attack ; while gardens D and F which are on the southern slopes show less *pollu* damage than those which are situated on the northern slopes. This observation is in conformity with the experience of the cultivators. But it is reported that it is very difficult to get the vines established on the southern slopes. In the early growing stages there are heavy casualties and even in later stages it seems that the vines on the southern slopes are more short-lived than those on the northern slope. For the reason, experienced cultivators do not choose lands on the southern slopes.

Another interesting observation made is that there is more *pollu* in the pepper gardens in the northern portions of Chirakkal taluk than in the south. In the north, which is the main centre of pepper cultivation in Chirakkal taluk, the chief variety cultivated is *Balam cotta*. In the other pepper-growing tracts the percentage of *Pollu* damage is low. Estimations made during the survey showed that it ranged from 3 to 10 per cent only.

#### *Spike shedding*

This is characterized by abnormal shedding of apparently healthy spikes during the ripening period. Microscopic examination of such shed spikes at different periods and from different vines showed that the great majority of them did not show any evidence of either fungus, insect or bacterial attack. The berries collected from shed spikes being immature, become very light and partially hollow on drying the degree of lightness depending on the stage of maturity at which shedding occurs.

Shedding of spikes has been observed to vary in intensity from year to year. It is very heavy in some years while it is tolerable in other years. Such failure is attributed to abnormalities of weather such as prolonged drought or prolonged rainy or cloudy weather. No figures are available to correlate spike shedding either to

drought or continuous rain. It is, however, clear that the great proportion of loss to the crop is due to shedding of immature spikes. The loss from *pollu* of insect and fungus origin has never exceeded 15 per cent while spike fall from unknown causes has by itself taken toll of up to 35 to 40 per cent of the crop.

### *Insect pests of pepper*

(1) Pepper flea beetle (*Longitarsus nigripennis*). This is the most important and specific pest of the pepper crop. It is a small shiny yellow and blue flea beetle—commonly called the pepper ‘*pollu beetle*’. The adult beetle makes a small circular hole in the rind of the berry, lays its eggs inside and covers it up with its excreta. The grub that hatches out, feeds on the kernel and makes the berry hollow. Attacked berries can be made out by the pale colour of individual berries and by the small hole drilled into it. The grub travels from one berry to another, a single grub eating the kernel of three or four berries before it becomes an adult. Sometimes the central part of the rachis of the spike is burrowed and eaten up by the insect. As a result the berries borne beyond the damaged portion do not develop for want of proper nourishment and become hollow and light.

### *Gall fly*

(2) This pest is a reddish maggot of the family *Cecidomyiidae* and attacks the young berries and checks their further development. In the young stages the maggot is transparent or pale white and is found imbedded on the tender tissues of the pulp, between the kernel and the attachment of the berry to the spike. It causes the formation of a gall chamber on the tissue of the pulp and so further growth is arrested. The maggot attacks and causes swellings on the tender leaves, leaf stalks and stem.

### *Scale insects*

(3) The pepper scale (*Lepidosaphes piperia*, G) is a small grey boat-shaped scale which is also specific on pepper, found attacking the main stem and leaves of infected vines. Badly infected vines dry up. This pest was noticed on the pepper vines in South and Central Travancore and the attacked vines were found dying.

### *Saissetia hemisphaerica*, Tark

(4) This is a common scale insect found attacking coffee, tea, cotton and ferns. It is a serious pest of coffee in the planting districts of South India. The scale is very convex and spherical in shape, and has a chocolate brown colour. This was found attacking the stems, spikes and berries of pepper in Coorg.

### *Mealy bug (Pseudococcus virgatus, T.)*

(5) The pest is found attacking leaves, stems and spikes. The vines sprayed with resin Bordeaux mixture at the Agricultural Research Station, Taliparamba

were found land attacked during the subsequent hot weather months. This was one of the reasons why Bordeaux mixture spraying against *pollu* had to be discontinued, though the spraying reduced *pollu*. It is possible that the mealy bug is kept in check by some beneficial fungi and the spraying might have destroyed those fungi.

### *Stem borer*

(6) The stems of pepper were found attacked by a stem borer. The markings of the borer damage was noted on the stems but the grubs and adults were not seen. The stem borer damage was noted in Travancore and Coorg but was not seen in other localities. The attacked vine wilts and dries up. The trouble in Coorg plantations seems, to some extent, to be due to borer damage as most of the wilted plants showed the markings of borer damage besides the root-rot. Further investigations are necessary to assess the damage caused by root-rot fungi and the part played by the stem borer in causing the death of the pepper plant.

## YIELD OF PEPPER

### *Normal yield of pepper*

The yield of pepper is seldom consistent. Besides the variety, the age of vine and the fertility of the soil, there are other important factors which go to determine the annual yield. The extent of the dry weather period, the period of first hot weather showers (blossom showers) which assist the formation of spikes, the weather conditions during flushing and fertilization, the period and intensity of the monsoon all exert some influence on the final yield. The number of effectively bearing vines in any year varies considerably from garden to garden with the result that it is never possible to correctly forecast or estimate the yield before the actual harvest season. In every garden there is considerable individual variation among the vines. In respect of yields, the vines can, however, be roughly sorted out into three groups : (a) Good yielders, i.e., those which yield well except under very abnormal seasonal conditions; (b) fair yielders which yield well in alternate years or once in about three years ; and (c) poor yielders which are consistently poor yielders. No attempt is made by the cultivator to replace the second and third sorts for reasons which are obvious. It takes from five to six years before any sizable yield is obtained from a newly planted vine and naturally the cultivator is reluctant to destroy the poorer vines and replace them with better strains or varieties. This is primarily due to the lack of initial knowledge on planting material and secondly the reluctance to destroy a grown up vine, however poor its performance may be. In this matter, it would be of immense assistance to the cultivator if he could be supplied with selected planting material of known qualities suitable for his tract from a central pepper research station. The Mysore Agricultural Department attempted some work in this direction at the Marathur Farm, but unfortunately the farm has since been closed down and the valuable work lost to the country.

Despite the obvious handicaps of correctly estimating the yields, an attempt is made in the following Tables to record the normal yields of pepper in the important pepper growing tracts and of well-known varieties of pepper in their natural habitat.

TABLE XII

*Showing the normal yields of pepper per acre in the important pepper growing tracts*

Year	Yield per acre in maunds			
	Malabar	South Kanara	Travancore	North Kanara
1st—3rd . . . . .	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>	<i>Nil</i>
4th—5th . . . . .	2	2	2	2
6th—7th . . . . .	4	6	4	4
8th—20th . . . . .	8	10	10	8
21st—25th . . . . .	6	6	4	5
26th—30th . . . . .	4	4	2	2

TABLE XIII

*Showing the average and maximum yields in pounds per vine of the important varieties of pepper*

Varieties	Wynaad		Kottayam		Chirikal		Mysore		North Kanara		Travancore		South Kanara	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Balamcottah	2—3	6	1½—1	5	2	6	2	6—7	..	..	..	..	..	..
Kalluvalli	1½—2	4	1½—1	6	2	6	1½—2	5—6	..	..	..	..	..	..
Karincotta	2—2½	5—6½	..	..	..	..	..	..	..	..	..	..	..	..
Cherlakodi	1½—2	4	..	..	..	..	..	..	..	..	..	..	..	..
Uthirankotta	1½—2	2	..	..	..	..	..	..	..	..	..	..	..	..
Tall Balam-cotta	..	..	1½—1	5—6	..	..	..	..	..	..	..	..	..	..
Molavalli	1½—4	..	1½—1	6	..	..	..	..	..	..	..	..	1½—2	6
Kottavalli	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Kottanadam	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Yollakanja-kadan	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Karuvilanchi	..	..	..	..	..	..	..	..	..	..	1½—2	6	..	..
Karimunda	..	..	..	..	..	..	..	..	..	..	1½—2	5	..	..
Mallesara	..	..	..	..	..	..	1—1½	4	1½—2	5	..	..	..	..
Kodiga	..	..	..	..	..	..	1—1	4	1	5	..	..	..	..
Tolisure	..	..	..	..	..	..	1—1	3	1	4	..	..	..	..
Morata	..	..	..	..	..	..	7	3	1	3	..	..	..	..

## THE PRICE OF PEPPER

The violent fluctuations in the price of pepper and the uncertainty of an estimable income from the pepper crop, has contributed in no small measure to the decline of the pepper industry in India. Table XIV shows that during a 20-year period between 1924 and 1943 the price has fluctuated between Rs. 15 and Rs. 112 per cwt. From 1924 to July 1925, the price ranged between Rs. 26 and Rs. 42 per cwt. Since then there was a gradual increase till the peak figure of Rs. 112 per cwt. was reached in February 1928. High prices ruled till the first-half of 1930. But,

by the end of 1930 with the general world depression, the prices dropped to Rs. 30 per cwt. In 1940-41, they reached the bottom mark of Rs. 15. The price of the produce fell far below the cost of production. The plight of the pepper growers, the majority of whom are small landholders or tenant cultivators became desperate. Unlike other perennial crops which can stand some amount of neglect, pepper cannot be neglected, for the land would be overgrown with weeds and jungle growth affecting the yields permanently. The two alternatives left to the pepper grower were either the abandonment of the garden or its maintenance at a loss. Many gardens inevitably went out of cultivation during this slump period. But many cultivators preferred to keep the garden going and as a losing concern. Most of them borrowed money from pepper merchants by mortgaging their property. In most cases, the grower was forced to sell away the standing crop in advance of the harvest to the merchant who arranged the harvest. Naturally, the cultivators did not realize even the extremely uneconomical market price for his produce.

TABLE XIV

*Showing the fluctuations in price of pepper during 20 years (1924 to 1943) in rupees per hundred weight at Tellicherry*

Year	January	February	March	April	May	June	July	August	September	October	November	December
1924 . . . . .	27	30	26	27	26	27	26	27	28	28	29	29
1925 . . . . .	29	30	31	32	33	37	48	46	52	56	59	77
1926 . . . . .	66	67	60	66	70	75	..	65	70	55	62	61
1927 . . . . .	49	60	60	62	80	100	90	100	102	100	95	92
1928 . . . . .	100	112	108	107	108	105	104	102	103	103	85	90
1929 . . . . .	91	90	91	90	80	92	96	92	94	90	88	70
1930 . . . . .	77	87	80	72	62	62	62	56	50	45	40	31
1931 . . . . .	32	36	31	31	31	31	35	36	37	38	40	42
1932 . . . . .	39	41	40	39	38	38	37	34	34	33	28	27
1933 . . . . .	26	26	21	25	35	31	30	29	26	24	23	26
1934 . . . . .	28	27	27	28	29	29	28	30	33	38	32	33
1935 . . . . .	33	28	27	28	26	25	26	24	25	25	22	21
1936 . . . . .	19	19	22	22	21	19	18	18	18	19	20	26
1937 . . . . .	22	21	22	22	21	21	21	22	22	20	19	18
1938 . . . . .	20	20	19	19	19	18	19	18	18	18	17	18
1939 . . . . .	19	18	18	18	18	18	16	16	18	18	20	18
1940 . . . . .	16	17	16	16	15	15	15	15	16	15	15	14
1941 . . . . .	15	16	15	15	17	20	19	17	16	17	18	19
1942 . . . . .	20	22	24	32	40	36	32	35	36	51	45	47
1943 . . . . .	50	71	82	82	80	70	75	71	72	65	60	63

‘ . . . the present market prices of pepper and cardamoms are below the costs of production and this position has been reached within the course of a few months following the announcement by the Export Trade Controller that exports of these species would be restricted to the level of 1940-41.

Both these crops are produced predominantly by small growers to whom they represent the only money crops possible under the climatic conditions of considerable areas of the Western Ghats and their foot-hills. Moreover, they are both ‘good’ money crops from the point of view of efficient land utilization in areas where faulty land utilization is fatally easy under considerable consequence to agriculturists over a far wider area than the actual pepper and cardamom districts. Therefore the economic well-being of these cultivators should be a matter of primary concern to the administrators concerned. Cardamoms and pepper had their full share of bad times which afflicted agricultural produces between the wars. Pepper prices fell in 1936 to little more than half the figure that stood at before the 1914-18 war and stayed at that level until 1941. The industry was barely able to survive such prices and would, in fact, have been completely destroyed were it not that the small holder producer fell back on his foodcrop production and contracted his cash expenditure to barest minimum. . . . In fact in both crops, substantial areas went out of production and in the case of pepper at least, a dead weight of surplus stocks kept the market comatose to point of extinction.’

With the invasion of Malaya and East Indies by the Japanese in 1942, the prices gradually rose and reached Rs. 82 per cwt. by March 1943. The announcement by the Export Trade Controller that the quota of export was fixed at the 1940-41 level had a sudden effect on the market. At the time of writing (June 1945) the market price is about Rs. 50 a cwt. The reasons for the sudden drop in prices were ably discussed in an editorial in *Planters' Chronicle*, dated 15th October, 1944.

From the foregoing it is apparent that in the interests of the cultivator there is the urgent need for the stabilization of the price of pepper in India. What has been effectively achieved in a commodity like coffee can be achieved in the case of pepper also. Until such stabilization of prices is achieved and the grower can look forward to a reasonable return for his labours the pepper industry would not offer the incentive which the cultivation of other crops like tea, coffee and rubber offers to the cultivators.

#### COLLECTION OF PEPPER VARIETIES

The following varieties of pepper were collected from the different pepper growing tracts and are being grown at the Agricultural Research Station, Taliparamba, for future work.

<i>Wynaad varieties</i> . . .	<i>Balamcotta ; Wynaad Kalluvalli ; Karincotta.</i>
Kottayam taluk . . .	<i>Balamcotta ; Kalluvalli ; Kallu Balamcotta ; Malavalli.</i>

South Kanara . . . : *Kottavalli*.

Travancore . . . : *Kottanadan* ; *Kaniakadan* ; *Perumkodi* ; *Karivilanchi* ; *Karivalli* ; *Mundi* ; *Munda* ; *Arikottanadan* ; *Thulakodi* ; *Kuthirawali* ; *Kumbakodi* ; *Chemala* ; *Karinthukara*.

Mysore and North Kanara *Morata* ; *Mallisara* ; *Doddiga* ; *Tattisara* ; *Mottukara* ;

*Wild varieties.* Wild pepper was collected from the following places :

- (1) Wynaad (Ma'abar), (2) Koni forest (Travancore), (3) Agumbe forest and Jog forest (Mysore), Mallalli (North Kanara). One of the wild varieties collected had spikes about 16 inches long, but setting of berries was extremely poor.

#### *Varietal resistance*

From observations made during the survey and enquiries from the cultivators it is gathered that *Kalluvalli* and *Karimeotta* can tolerate seasonal variations and diseases better than the other Malabar varieties. Among the Travancore varieties it is reported that *Karivilanchi*, *Valia Kaniakadam* and *Karivalli* are more hardy than the others. In Mysore, *Mallisara* and *Toddiga* withstand the variations better than the other Mysore and North Kanara varieties. It was not possible to make anything more than a cursory estimate of these factors from enquiries made of experienced growers.

#### SUMMARY AND CONCLUSIONS

The survey has indicated the need for detailed information on a variety of problems connected with the pepper industry which would make the cultivation of pepper a remunerative enterprise which it is not at present. These problems are :

- (1) Selection of existing high yielding varieties.
- (2) Evolution of better varieties from the point of view of yield, regular bearing, drought resistance and resistance to pests and diseases.
- (3) Improvement in cultural practices with a view to conserve moisture during dry months.
- (4) Complete knowledge of the manurial requirements of the pepper plant and the method, doses and period of application.
- (5) The relative merits of various standards and the proper methods of their maintenance in respect of the regulation of shade.
- (6) The control of pests and diseases.
- (7) Stabilization of prices.

#### *Selection of high yielding varieties*

The survey has shown that there is a wealth of genetically varying material available, but no systematic effort has been made to study their characters or their performances under similar conditions. The fact that pepper is propagated vegetatively, which affords scope for the rapid multiplication of selected material, should be taken advantage of to study the performances of all promising varieties at a central research station.

*Evolution of better types*

Not one of the existing varieties was produced by human effort at plant breeding. In a crop like pepper where cross pollination is the rule and hybrid progeny can be vegetatively multiplied at any stage of evolution, it should be possible to produce plants with a number of desirable characters in them. This is the work of a plant breeder.

*Improvement of cultural practices*

There is wide range of variation among the cultural practices followed in different tracts. A series of well laid out agronomic experiments at a central research station should furnish all the information required on this line. The points requiring elucidation are methods of planting, soil conservation, weeding, layering and regulation of shade.

*Manurial requirements of pepper*

The experiments at Taliparamba and Konni have shown that pepper responds to manuring. But, as mentioned in this report, the experiments have not been carried out with that degree of exactitude and precision which a crop like pepper demands by virtue of the variability in planting material, standards, shade, aspect, etc. It is therefore necessary to carry out adequately controlled manurial experiments to study the precise manurial requirements of the crop. In any scheme of research, this aspect should receive adequate attention.

*Standards*

There is difference of opinion about the choice of standards. Precise information is required on the most suitable species, the methods of their propagation and maintenance. The question of shade is intrinsically connected with the species of standard chosen, its feeding habits, longevity and the periodic treatment it receives.

*Pests and diseases*

Pepper in India suffers from a variety of pests and diseases. Root diseases are a problem by themselves but the existing knowledge about them and the measures of controlling them are woefully inadequate. From all accounts the prevention of root diseases appears far more feasible than their cure. While the direct preventive treatments are not ruled out, the modification of cultural and manurial practices and the employment of varietal resistance as a means of control appears more promising than direct methods. *Pollu* is the bane of the pepper industry in certain tracts. It is, however, a complex problem in which a fungus two insects and an apparently physiological phenomenon known as 'spike shedding' are involved. Here again experiments carried out at Taliparamba point to the limitations of direct control methods. Spike-shedding is a factor which calls for attack from the agronomic front. The apparent resistance of certain existing varieties to insect and fungus attacks can be explored with a view to evolve one or more varieties resistant to them.

## ACKNOWLEDGEMENTS

During the survey, many individuals, both officials and non-officials, were of great assistance. I express my gratitude to all of them. In particular, I wish to thank the Directors of Agriculture, Travancore, Cochin and Mysore States, the Plant Pathologist to the Government of Bombay, the Rural Development Officer, North Kanara, the Agricultural Officer, Coorg, Mr. Ivor Bull, Managing Director of the Consolidated Coffee Estates (1943), Limited, and the District Agricultural Officers of Malabar and South Kanara for planning my tour and affording assistance within their respective jurisdiction.

My special thanks are due to Mr. K. M. Thomas, Government Mycologist, Coimbatore, for guidance throughout the survey, for reading through my manuscripts and moulding the paper in the form in which it is presented.

## REFERENCES

- Anandan, M. (1929). Observation on the habits of pepper vines with special reference to its reproduction phases. *Madras Ag. Dept. Year Book*, 1924, 49—69
- Barbar, C. A. (1906). The varieties of cultivated pepper. *Mad. Agr. Dept. Bull.* No. 56
- Basu, B. C. (1898). Cultivation of Black pepper in Assam. *The Agr. Ledger* No. 7
- Govinda Kidavu, M. (1929). Manurial and cultural experiments. *Mad. Agr. Stn. Rept.*, 1928-29, 27
- Govinda Kidavu, M. and Venkateswaran (1928). Pepper cultivation on the West Coast. *Mad. Agr. Dept. Bull.* No. 98
- Milsum J. N. (1930). Pepper in Malaya. *The Malayan Agr. Jour.* XXVII, 274-280
- Ramchandra Rao, Y. and Ramaswamiah, A. G. (1924). Notes on the life history of (*Longitarsus nigripennis*) the pollu flea-beetle of pepper. *Mad. Agr. Dept. Year Book*, 1926, 31—64
- Ramakrishna Ayyar, T. V. (1944). Handbook of economic entomology for South India, 342; Govt. Press, Madras, 1944
- Redgroves, H. S. (1933). Spices and condiments—Pepper, 74
- Sharples, A. (1922). Preliminary and detailed report on 'black fruit disease of pepper vines in Sarawak, Govt. Print. Office, Kuching, Sarawak, 15.
- Sivaraman Pillai, G. (1936). *Proceedings of the first meeting of the Board of Agri. in Travancore-Pepper*, 110-118
- Thomas, K. M. and Krishna Menon, K. (1939). The present position of pollu diseases of pepper in Madras. *The Mad. Agr. Jour.* XXVII, 348
- Yegnanarayana Ayyar, A. K. (1930). Pepper in Mysore. *The Journal of the Mysore Agri. and Experimental Union.* XI No. 1, 11
- Yegnanarayana Ayyar, A. K. (1944). *Field crops of India—Pepper*, 281, Govt. Press Bangalore
- of the manurial experiments on the Agricultural crops of the Madras Presidency for the decennial period 1930—40—Pepper. *The Mad. Agr. Jour.* XXXII, No. 2, 45.
- Season and crop reports of the Madras Province 1933-34 to 1942-43
- *International year book of Agricultural Statistics, Rome*, 1938-39
- Leefmans, S. (1933). Disease and pests of cultivated crops in the Dutch East Indies in 1930. Abstract in *Rev. App. Myc.* 12, 425.
- Muller, H. R. A. (1937). The Phytophthora foot rot of Pepper in the Dutch East Indies. Abstract in *Rev. App. Myc.* 16, 559.
- Vinukatananda, Y. Y. and Celino, M. S. (1940). Anthracnose of Black pepper. *Philipp. Agr.* XXIX, 2, 124-141, 1940. Abstract in *Rev. App. Myc.* 19, 728

March, 1949 ]

SURVEY OF POLLU AND ROOT DISEASES

APPENDIX I

Statement showing the distribution of the annual rainfall on representative localities of pepper growing tracts

	January	February	March	April	May	(In inches)		August	September	October	November	December	Total
						June	July						
<i>Wynaad</i>													
Kalpette	1.22	0.11	0.56	6.06	10.17	20.22	41.36	17.25	7.82	10.27	4.77	1.85	130.46
Sultan Battery	2.85	..	0.15	5.02	6.93	15.37	20.72	10.89	8.19	9.92	4.21	1.48	80.73
Manantoddy	..	..	0.52	4.16	6.70	23.04	38.75	16.17	7.44	5.46	3.26	1.11	106.61
<i>Malabar</i>													
Taliparamba	..	..	0.06	3.85	4.95	36.31	51.35	20.23	10.17	8.23	6.02	0.10	140.34
Tellicherry	0.93	0.45	..	4.76	11.78	39.50	33.67	12.46	6.48	9.89	6.02	2.03	127.45
<i>South Kanara</i>													
Nileshwar	0.04	0.05	0.01	3.50	6.20	41.29	54.11	22.57	9.94	5.86	4.13	0.70	148.40
<i>North Kanara</i>													
Sirsi	0.03	..	0.44	1.69	2.31	22.28	34.37	22.59	7.73	7.11	2.00	0.23	100.73
<i>Coorg</i>													
Sidapur	0.43	..	0.65	2.89	7.88	8.71	16.40	9.18	3.20	7.62	3.95	1.54	82.84
Santikoppa	0.86	..	0.27	3.87	6.63	10.61	17.43	3.92	6.46	4.63	1.37	66.82	
Pollibetta	..	..	0.55	4.05	8.65	18.50	14.55	9.95	3.35	5.90	0.40	0.52	64.42
<i>Mysore</i>													
Thirthahalli	0.38	..	..	0.35	14.32	17.74	62.88	9.59	13.47	10.95	1.50	..	131.18
<i>Travancore</i>													
Attingal	0.48	1.20	3.03	4.75	8.55	8.50	4.95	2.80	6.27	7.32	1.93	0.35	50.13
Konni	2.00	2.50	6.75	8.20	15.77	16.10	11.11	5.76	9.88	11.46	1.50	0.35	91.88
Muvattupuzah	0.59	1.06	5.88	6.50	17.85	25.37	10.60	7.65	10.07	13.23	1.05	0.35	100.20

APPENDIX II

Table showing the area of pepper, and export in the Madras Presidency and Travancore State during the years 1933-34 to 1942-43

Year	Travancore*			Madras†			†Figures not available
	Area in acres	Export	Area in acres	Export			
				Foreign	Coastwise	Total	
1933-34	79,302	230,000	97,011	50,633	..†	..	
1934-35	75,901	128,200	95,745	60,681	..	..	
1935-36	84,270	172,580	97,981	24,939	..	..	
1936-37	90,911	126,680	102,924	23,326	..	..	
1937-38	90,388	182,740	104,081	16,148	..	..	
1938-39	89,325	202,840	102,819	15,237	143,343	158,580	
1939-40	86,367	299,220	104,384	16,037	102,598	118,635	
1940-41	87,261	264,260	104,112	9,395	64,156	73,551	
1941-42	88,263	215,400	105,019	30,275	208,560	233,835	
1942-43	69,159	244,300	103,255	53,531	125,997	179,528	

\*Travancore. Total export. Figures kindly furnished by the Director of Food Supplies

Travancore. Area (acres) Figures kindly furnished by the Director of Agriculture,

Madras. Figures from the Season and Crop Reports, Madras Province.

## APPENDIX III

*Statement showing the chief characteristics of the common cultivated varieties of pepper*

Variety	Tracts where commonly cultivated	Time of flowering	Period of harvesting	Size of leaves	Length of spikes	Percentage of dry to green pepper	Remarks
Kottanadan	South and Central Travancore	June-July	February—March	14.0 × 8 cm.	7.0—13.5	43	Good climber, yearly bearing and a heavy yielder. One of the best varieties
Kanaikadan	Central and North Travancore	May-June	January—February	14.0 × 6 cm.	7.5—16.5	42	Good climber, yearly bearing and a heavy yielder. One of the best. Two distinct subdivisions, Valia and Cheria
Perunkodi	Central and North Travancore	May-June	January—February	13.0 × 7 cm.	10.5—17.5	40	Medium climber, yearly bearing and a good yielder.
Karivilanchi	South and Central Travancore	May-June	January—February	12.5 × 8 cm.	6.0—14.0	36	Medium climber, yearly bearing and a good yielder, a good variety favoured by cultivators and traders. A hardy plant allied to Kaluvalli
Karivalli	Rani	May-June	December—June	16.5 × 10.5	11.0—19.5	40	Good climber, bears in alternate years
Mundi	North Travancore	May-June	November—December	14.0 × 7.5	7.0—13.5	37	Medium climber, yearly bearing and a good yielder, a hardy and an early variety
Munda	Central North and Travancore	May-June	December—January	11.5 × 7.5	6.0—14.0	36	Medium climber and a poor yielder
Arikottanadan	South and Central Travancore	May-June	January—February	15.0 × 11.75	7.5—14.0	36	Medium climber and a good yielder
Thulakodi	Central Travancore	Apr.-May	October—November	13.5 × 8.5	6.5—12.5	34	Medium climber, yearly bearing, a good yielder and an early variety

March, 1949 ]

SURVEY OF POLLU AND ROOT DISEASES

Kuthiravali	South Travancore	May-June	January— February	13.5 × 9.25	11.0—17.0	36	Medium climber, yearly bearing and a good yielder.
Kumbakodi	Central Travancore	May-June	February— March	13.5 × 9.5	8.0—14.5	34	Good climber, yearly bearing, a good yielder and a late variety
Chumala	Rani	Apr.-May	October— November	18.5 × 10.25	11.0—16.5	33	Good climber, yearly bearing and an early variety
Karinghachara	Central Travancore	May-June	December— January	12.0 × 7.0	5.5—13.0	37	Bold climber, a good yielder but bears only in alternate years
Balamcottta	Kottayam, North Malabar	May-June	January— February	19.0 × 11.0	12.5—19.5	38	Good climber yearly bearing and a good yielder
Kalluvalli	North Malabar	May-June	January— February	17.0 × 9.1	8.5—17.0	42	Medium climber, yearly bearing and good yielder. A hardy plant
Cheriakodi	North Malabar	June-July	January— February	15.5 × 6.75	5.5—9.5	38	Medium climber, bears in alternate years
Uthirancottta	North Malabar	Apr.-May	November— December	16.25 × 8.4	10.5—19.0	38	Good climber produces vegetative runner in large numbers but a poor yielder
Karincottta	Wynaad	June-July	February— March	16.40 × 9.5	7.5—11.5	42	Good climber, yearly bearing, a good yielder and a hardy plant
Mallisara	North Kanara	June-July	January— February	17.76 × 12.0	8.0—12.0	42	Medium climber, yearly bearing and a heavy yielder
Doddiga	North Kanara	June-July	January— February	19.35 × 11.55	7.5—10.5	38	Medium climber and a uniform yielder
Mettukara	North Kanara	June-July	January— February	15.0 × 13.0	5.0—8.0	38	Bold climber and a uniform yielder

## APPENDIX IV

*Statement showing the soil analysis (chemical) of some of the pepper growing tracts*

No.	Locality	Loss on ignition	F <sub>2</sub> O <sub>3</sub>	CaO	Mg	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	SO <sub>2</sub>	N	Av. K <sub>2</sub> O	Av. P <sub>2</sub>
1	South Wynaad (Malabar)	11.69	18.48	0.15	0.26	0.44	0.123	0.10	0.008	0.004	0.262
2	North Wynaad (Malabar)	11.57	33.72	0.11	0.16	0.436	0.178	0.10	0.011	0.006	0.082
3	Pollibetta (Coorg)	7.30	10.79	0.33	0.19	0.20	0.17	..	0.166	0.033	0.026
4	School Estate (Coorg)	5.05	15.95	0.25	0.60	0.25	0.10	0.10	0.164	0.002	0.016
5	Sidapur (Coorg)	9.08	19.03	0.217	0.249	0.117	0.250	0.084	0.157	0.022	0.013
6	Mundakayam (Travancore)	13.00	16.68	0.028	0.077	0.365	0.112	0.084	0.165	0.019	0.021
7	Kottayam (Travancore)	12.29	22.44	0.26	0.53	0.31	0.05	0.19	0.126	0.113	Trace
8	Kadur (Mysore)	6.79	39.91	0.061	0.214	0.081	0.026	0.004	0.004	0.004	0.001

*Statement showing the soil analysis (mechanical) of some of the pepper growing tracts*

No.	Locality	Fine gravel	Coarse sand	Fine sand	Silt	Fine silt	Clay	Organic matter
1	South Wynaad (Malabar)	..	30.57	23.83	7.66	15.31	6.91	11.69
2	North Wynaad (Malabar)	..	17.40	17.57	10.32	21.84	18.49	11.57
3	Pollibetta (Coorg)	7.47	29.8	31.0	6.3	8.0	12.5	7.30
4	School Estate (Coorg)	..	26.2	29.5	5.1	12.9	19.6	5.05
5	Sidapur (Coorg)	1.50	18.95	38.58	4.42	17.51	18.75	9.08
6	Mundakayam (Travancore)	5.5	28.90	14.90	8.36	22.83	16.93	13.00
7	Kottayam (Travancore)	5.3	53.41	16.90	1.92	1.31	3.21	12.29
8	Kadur (Mysore)	..	17.00	14.55	23.12	21.56	17.54	6.79



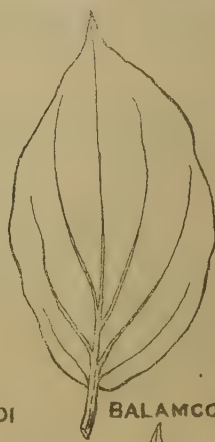
Map showing important pepper growing tracts of South India



KALLUVALLI



CHERUKODI



BALAMCOTTA



KOTTAVALLI



KARINCOTTA



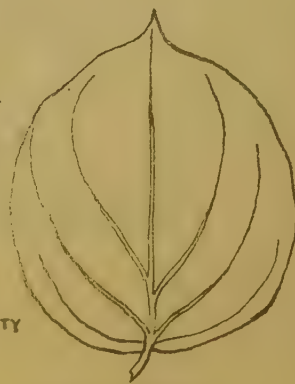
MALLISARA



NODDIGA



TRAVANCORE  
SPREADING VARIETY



METTUKARA

## STUDIES IN THE CLARIFICATION OF SUGARCANE JUICE IN GUR MANUFACTURE

By K. L. KHANNA and A. S. CHACRAVARTI, Central Sugarcane Research Station, Pusa, Bihar

THE manufacture of *gur* in India is a cottage industry of first class importance in that it accounts for over 60 per cent of the cane crop grown in the country. Being almost entirely in the hands of the small cultivator, the industry is inevitably associated with crude and inefficient methods, resulting in considerable losses in quality as well as quantity on account of which the cultivator is put to a great disadvantage. The need for improved methods has been strongly felt and attempts made from time to time to achieve progress in this direction.

Juice clarification is perhaps the most important factor in obtaining a product of high quality and is more often than not, sadly neglected. While some varieties of cane may give rise to satisfactory products without much care being bestowed on this process, it is essential with varieties giving rise to juices of poor inherent claribility to resort to some very efficacious juice treatment.

Several methods of clarification known in *gur* manufacturers' practice are mentioned in the report on the marketing of sugar in India and Burma [1943], such as the mucilaginous extract of the green stems of *deola* (*Hibiscus ficulenus*) and *bhindi* (*Hibiscus esculentus*) and the bark of *sukhlai* (*Kydia calycina*). The extract of *falsa* bark (*Grewia asiatica*) is also used, though it is not mentioned in the report. These agents, while undoubtedly promoting better quality, are not effective enough to answer the needs of poor claribility juices. Milk is also sometimes used in juice clarification but it is too expensive to be practical. Lime water or diluted milk of lime is used in some parts of the country but although lime has a binding and neutralising effect, which is particularly helpful in dealing with diseases or logged canes with high acid content, the use of this material imparts a very dark colour to the product. 'Blankit' (sodium hydrosulphite) is some times employed with a view to bleaching and improving the colour of *gur* but the good colour of the product so obtained begins to deteriorate very fast. Further, excessive use of this chemical which is quite common, imparts an unpleasant sulphur taste. The process of treating the juice with activated carbon from paddy husk, while giving a high grade product, involves a particularly heavy cost hardly within the means of the small cane growers, apart from detracting greatly from the simplicity of the manufacturing process and considerably lowering the yield.

The coagulating effect on colloids of electrolytes (acids, alkalis and salts) being well known, particularly of those giving rise to high valency ions, their application in the clarification of juice for *gur* manufacture was considered of particular interest. In these experiments [Khanna, 1945, 1946], an exhaustive study of the effect of

a number of electrolytes was undertaken, sometimes used in conjunction with the common preparation—*bhindi* mucilage. A new process of clarification was also developed and its efficiency examined in relation to other treatments, using a large number of cane varieties for comparison. The experiments were conducted over three successive seasons.

## EXPERIMENTAL

### (a) Clarification with electrolytes

The electrolytic clarifying agents were added at the rate of 20 to 25 grams per maund of juice before the boiling commenced and the scum was removed carefully as it formed. The process of manufacture was the same as is usually followed. Two varieties of cane, viz. Co 313 and Co 453 were used in the experiment. In the case of Co 313, the following electrolytes were used : (1) Sodium carbonate, (2) sodium carbonate with *bhindi* mucilage, (3) sodium bicarbonate, (4) sodium bicarbonate with *bhindi* mucilage, (5) potassium carbonate, (6) acetic acid, (7) acetic acid with *bhindi* mucilage, (8) citric acid, (9) aluminium sulphate, (10) aluminium sulphate with *bhindi* mucilage, (11) alum, (12) alum with *bhindi* mucilage, (13) caustic soda, (14) caustic soda with *bhindi* mucilage, (15) ferric chloride with *bhindi* mucilage. Treatment with *bhindi* mucilage was the basis of comparison. The undermentioned electrolytes were used with Co 453:—(1) Double Superphosphate with *bhindi* mucilage, (2) caustic soda with *bhindi* mucilage, (3) sodium carbonate (4) acetic acid. *Bhindi* mucilage treatment here was also included for comparison.

### (b) Clarification by a new process

This process consists in the clarification of juice by a water extract of crushed castor seeds (*Ricinis communis*) which is prepared by grinding the seeds, taken together with some water in a mortar. The resultant milky liquid is strained through cloth and collected in a vessel to be used as the clarifying agent. The seeds are treated in the same way with further quantities of water, so long as a milky liquid continues to be formed after which the exhausted seeds are replaced by fresh ones. In treating two maunds of juice, the extract of one chhatak of castor seeds (weight including shell) is used. About half the quantity is added before boiling commences, the remaining half being gradually sprinkled on the juice during the course of boiling and the scum being carefully removed as it forms. The addition is discontinued (at a temperature of 102-103°C.) before the *rab* stage is attained.

A further simple modification in the processing technique is adopted, viz. the pan contents after strike are briskly agitated with a stirrer (rather more vigorously than usual) before the material is transferred into moulds.

The method was tested against the *bhindi* mucilage treatment with reference to a large number of varieties in the first two crushing seasons. An exactly similar extract of groundnuts was also examined in the second season and the quality of the product obtained from several varieties evaluated with respect to those of the castor seed extract and *bhindi* mucilage treatments.

In the third season, a statistically planned experiment in respect of the three treatments with four varieties (Cos 313, 383, 453 and 513) in four replications was carried out under carefully standardised conditions wherein each pan was struck at the same temperature (118°C.) recorded with precision.

Similar experiments were also conducted to ascertain the relative merits of the three treatments with reference to immature canes (early in October) and water-logged canes giving rise to juices of abnormally high colloid content (1.433 to 1.564 per cent).

A set of experiments to compare the efficacy of the castor seed and groundnut extracts with the extracts of *deola* and *falsa* bark (in common use in the United Provinces) was also performed.

### (c) *Evaluation of the end-product with respect to quality*

All samples of *gur* resulting from these experiments were examined in respect of general features such as hardness, texture, taste and colour. In addition, they were also analysed for the following important physical and chemical criteria—sucrose, glucose, moisture, acidity, pore space, intensity of colour of standard solutions and relative amounts of suspended impurities, as indicated by “turbidity” of standard solutions. In the experiments conducted during the third season—ash contents were also determined and Nett Rendements (=sucrose per cent—glucose per cent— $3.5 \times$  ash per cent) calculated. The methods of determination have been described in a previous communication [Khanna and Chacravarti, 1949].

The observations on the various samples of *gur* prepared from the varieties Co 313 and Co 453 by the addition of different electrolytes are shown in Table I. In Table II, the results obtained during the first season with the castor seed extract treatment are shown against *bhindi* mucilage for a number of cane varieties. Table III incorporates similar data pertaining to the second season, wherein the performance of groundnut (*Arachis hypogaea*) extract is also brought out. Table IV sets out the results of the third season showing the behaviour of the three treatments in respect of four varieties in four replications. The data for immature and water-logged canes are contained in Tables V and VI respectively. Table VII provides a comparison of the castor seed and groundnut extract treatments with *deola* mucilage and *falsa* bark extract. Tables VIII to XII briefly depict the results of analysis of variance performed in respect of the different experiments of the third season stated above. Table XIII shows certain chemical features of the extracts of castor seeds, groundnuts, *bhindi*, *deola* and *falsa* bark, Table XIV the average yields of *gur* by different treatments.

### DISCUSSION OF RESULTS

A reference to Table I will give an idea of the quality of *gur* obtained by means of the various juice treatments with Co 313 and Co 453. In what follows, a comparative discussion of the different clarifying agents—electrolytic and otherwise—has been undertaken so as to arrive at a correct estimate of their efficacy and select the most effective clarification process.

First considering the results with Co 313, it will be seen from the general observations that all samples are hard, crystalline and of good taste, variation being observed only in colour. The following treatments may be said to produce good colour (golden yellow or brilliant golden), the rest yielding *gur* of an undesirable (red) colour :

(1) *Bhindi* mucilage, (2) castor seed extract, (3) sodium carbonate, (4) sodium carbonate with *bhindi* mucilage, (5) sodium bicarbonate, (6) sodium bicarbonate with *bhindi* mucilage, (7) acetic acid, (8) acetic acid with *bhindi* mucilage, (9) citric acid.

A quantitative gradation in respect of the intensity of colour is available in the colour readings of 1/4 normal solutions, taken with the Photo electric colorimeter. It will be seen that a considerably lower reading is recorded with the castor seed extract treatment (55) and among the other treatments mentioned above, the values for Nos. (1), (3), (4), (5), (6) and (8) are the lowest, varying between 85 and 100. Treatments (7) and (9) show somewhat higher values 120-130. All samples other than those enumerated above, which are red in colour, record considerably higher values, varying between 130 and 200.

Differences in sucrose, glucose, moisture and acidity values are not systematic but the figures for turbidity in case of the castor seed extract treatment are distinctly lower than all others, showing the presence of the least amount of suspended impurities. This treatment, followed closely by *bhindi* mucilage is associated with the highest pore space values, i.e. open texture.

Considering these facts, it may be said that the castor seed extract treatment gives a product of outstanding quality, not approached by any other with respect to the very light and attractive shade of colour. Treatment with sodium carbonate or sodium bicarbonate, either alone or with *bhindi* mucilage, also produces fairly good quality but the use of these electrolytes appears to yield no particular advantage over *bhindi* mucilage, used alone. Acetic acid or citric acid also proves fairly efficacious but are distinctly inferior to *bhindi* mucilage. All the other electrolytes examined are clearly of not any use in that they yield red coloured products when the common *bhindi* mucilage itself is capable of giving golden yellow *gur*.

Coming to Co 453, it is found that all samples are hard but none of them is quite crystalline except the product of the castor seed extract treatment, which is fairly crystalline. The taste is good in all cases except one. The colour is dark chocolate with *bhindi* mucilage and dark red with the rest with one exception, viz. for the castor seed extract, in which case the product is cream coloured. The figures for intensity of colour show a low value (95) for the castor seed extract treatment as against 200 for *bhindi* mucilage. Other clarificants showing somewhat lower values than *bhindi* mucilage are sodium carbonate (185) and 'Double super used with *bhindi* mucilage' (165) but the improvement can hardly be called substantial.

Sucrose contents are generally of the same order. With respect to glucose, moisture and acidity no appreciable differences are observed. The pore space value is the highest for the castor seed extract treatment.

In view of the very good results obtained with the castor seed extract process with the varieties Co 313 and Co 453 (particularly the latter, as it ordinarily yields very dark coloured *gur*), several other varieties were treated by this process and the

results judged against the common *bhindi* mucilage clarification process. In Table II has been included a comparison of the properties of *gur* from all these varieties prepared during the first season by the two processes. It will be seen that Co 513 like Co 313, yields brilliant golden end-product by the new process as against the rather dull golden yellow colour obtained with *bhindi* mucilage. Co 395 and B. O. 3 yield pale yellow *gur* by this method instead of the deep red stuff resulting from *bhindi* mucilage clarification and the difference is more conspicuous in these cases. It is most striking for Co 453 which yields cream coloured *gur* in contrast to the dark chocolate obtained with *bhindi* mucilage and further, the crystalline nature is distinctly enhanced in this case. A reference to the figures for colour intensity further supports the above observations.

So far as sucrose, glucose and moisture contents are concerned, there appears to be no systematic difference and this may be said of the acidities as well. Pore spaces are in most cases distinctly higher for the castor seed extract treatment, showing that the process tends to yield end-products with more open texture. Similarly, the smaller values for the turbidities of standard solutions of *gur* samples prepared by this treatment indicate smaller concentrations of suspended impurities present in them.

The data pertaining to the second season (Table III) which refer to a large number of varieties, fully corroborate the above observations. It further appears that the extract of groundnuts is as effective as that of castor seeds and possibly more so in several cases.

The data collected in the third season will be found in Table IV. These experiments were conducted with respect to four varieties in four replications (Cos 313 383, 453, 513) under carefully controlled conditions, the temperature of strike (118°C.) being recorded with precision. Analysis of variance done in respect of the different characteristics of *Gur* (*vide* Table VIII) show highly significant differences between treatments for several properties. Thus, the castor seed and groundnut extract treatments give rise to higher values for pore space (denoting a more open texture) and lower figures for colour and turbidity in standard solutions (indicating lightness of colour and smaller amounts of insoluble suspended impurities). The superiority of these two treatments over *bhindi* mucilage is thus clear. As between castor seed and groundnut extract differences are not significant but the latter shows a superior trend in respect of almost all the properties. The fact that Nett Rendement values under the different treatments are non-significant shows that none of them significantly affects refining qualities.

A comparison of the three treatments with respect to immature canes (early October) will be seen in Table V and the results of analysis of variance in Table IX. Here again, most of the values show highly significant results in favour of the castor seed and groundnut extracts and while the difference between these two is non-significant, the superiority of the latter in most cases is clearly noticeable. Nett Rendement differences are non-significant for the three treatments. The performance of the two extracts in respect of immature canes brings out their effectiveness in a difficult case.

Table VI incorporates data on water logged canes, giving rise to juices of abnormally high colloid content (1.433—1.564 per cent). The results of analysis of variance are set out in Table X. What has been said for immature canes will be seen to apply equally well here and it would thus appear that the castor seed and groundnut extract treatments adequately meet the case of juices of abnormally poor quality, ordinarily resulting in low grade products.

Tables VII, XI and XII provide a comparison of the properties of *gur* prepared by the castor seed and groundnut extract treatments with those of products resulting from treatment with the mucilages of *deola* and *falsa* bark—clarifying agents commonly used in the United Provinces. It will be seen that the colour values of the castor seed extract treatment are conspicuously lower than those under *deola* and *falsa* extracts and that the differences are highly significant. In respect of most other characters, the superiority of the castor seed extract treatment, although not statistically significant, is systematically manifested. Similar behaviour is met with in case of groundnut extract also where superiority not only in colour but in turbidity as well is highly significant. Higher pore space is also apparent in respect of this treatment. The *falsa* bark extract treatment proves systematically inferior to *deola* mucilage in respect of most characters and this conforms to general experience in the United Provinces, where *deola* mucilage is believed to be by far the more effective of the two treatments.

It can be safely concluded from the above observations that clarification by castor seed or groundnut extract is definitely superior to that obtained with *bhindi*, *deola* or *falsa* mucilage and a number of electrolytic substances. It also gives quite good results with juices of immature canes and also water logged canes, abnormally rich in colloids which normally yield inferior products. The same observation has been made with respect to canes badly damaged by termites (Colloids 1.185 per cent on juice) although the figures are not included here. It has been seen in the various statistical tables that the Nett Rendement is not adversely affected by this process. The yield of *gur* on juice is also unchanged, as shown by average data (Table XIV). The method of clarification, therefore, undoubtedly constitutes a remarkable improvement. The materials (castor seeds or groundnuts) are within easy reach of the small cane grower, involving an expenditure of hardly more than half anna or so per maund of *gur*. In view of the small quantities used, the loss by way of oil and cake (otherwise available) is negligible.

It was considered interesting to enquire into the chemical characteristics of the different organic clarifying extracts, so as to open the way for ultimately developing a universally applicable ready-made product. The materials (castor seeds, groundnuts, *bhindi* and *deola* stems and *falsa* bark) were extracted with 20 times their weight of water, filtered through cotton wool in the first two cases and strained through cloth for the rest. The preliminary determinations included, crude proteins, true proteins, ash content,  $P_2O_5$ , sol.  $SiO_2$  and the oxides of the higher valency metals, Ca, Mg, Al and Fe. The results are expressed as milligrams of the ingredient per 100 cc. of the extract (Table XIII). The castor seed and groundnut extracts which showed outstanding clarifying power clearly possess the following characteristics :

- (i) they are very much richer in crude proteins,
- (ii) the same holds good for true proteins,
- (iii) the ratio of true proteins to crude proteins is remarkably high,
- (iv) phosphate contents are distinctly higher.

The important role of proteins and phosphate in determining clarifying properties is thus apparent. The possibility of a certain amount of adsorption of juice colloids at the liquid—liquid interface (oil-juice) cannot also be ruled out.

#### SUMMARY AND CONCLUSIONS

The manufacture of *gur* consumes by far the greater part of the cane crop grown in the country and must therefore be regarded as a very important agricultural industry. Being almost entirely in the hands of the small cultivator, the industry is inevitably associated with crude and inefficient methods, as a result of which the product suffers greatly in quality as well as quantity. The need for improved methods is, therefore, imperative.

Juice clarification is perhaps the most important factor in obtaining good quality products but is apt to be neglected. The need for effective clarification is most pressing in case of cane varieties giving juices of poor claribility, which call for efficient clarifying treatments so as to give end-products of high quality.

In view of the well known property of electrolytes (acids, alkalis and salts) of coagulating colloidal solutions, a study of a series of electrolytes was undertaken in respect of their efficacy in juice clarification, with reference to the well known clarifying agent, *bhindi* mucilage (*Hibiscus esculentus*) as a basis of comparison. A thorough qualitative and quantitative examination of the *gur* samples prepared by different treatments in respect of general features and important physical and chemical criteria leads to the conclusion that none of the electrolytes used is capable of giving any better results than the common *bhindi* mucilage. In fact, some of the electrolytes are decidedly inferior in respect of the quality of *gur* obtained. The use of these electrolytes for juice clarification cannot, therefore, be advocated.

A novel process involving clarification with a water extract of castor seeds or groundnuts followed by a slightly modified processing technique, produced outstanding results, far surpassing the *bhindi* mucilage treatment and all the electrolytes in efficacy. It is also very much superior to *deola* and *falsa* bark extracts—clarificants in vogue in the United Provinces. The process also gives very good results with immature canes as well as juices of abnormally high colloid content, e.g. water logged or termite infested canes. The method is very cheap and pre-eminently suited to village conditions, being at the same time capable of producing high quality *gur* from juices of poor claribility. Its adoption would, therefore, prove of great benefit to the *gur* industry.

Certain chemical characteristics of castor seed and groundnut extracts are recognised which obviously induce superior clarifying power.

## ACKNOWLEDGMENT

This work was conducted as part of the Sugarcane Research Scheme in Bihar being financed jointly by the Government of Bihar and the Indian Central Sugarcane Committee, to whom grateful thanks are due. The authors also wish to acknowledge the assistance rendered by Mr. K. S. Bandopadhyay, Statistician, in statistically analysing data presented in the paper.

## REFERENCES

- Report on the marketing of sugar in India and Burma, *Government of India, Marketing Series No. 39* (1943)
- Khanna, K. L. (1945)—*Ann. Rept. Cent. Sugarcane Res. Sta.*, Pusa, Bihar, p. 20
- (1946)—*Ann. Rept. Cent. Sugarcane Res. Sta.*, Pusa, Bihar, pp. 35-37
- Khanna K. L. and Chakravarti, A. S. (1949)—*Proc. Ind. acid. Sci.* 29 (5).

TABLE I

Showing properties of Co 313 and Co 453 gur prepared by different treatments  
Co. 313

Serial No.	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space. (cc/100g)	Colour reading	Turbidity	Millieq. acid in 100 g.	General observations
						N/4 solution			
1	Bhindi mucilage	80.6	4.79	5.06	26.8	95	2.00	12.9	Hard, crystalline, taste good, colour golden yellow
2	Castor seed extract	80.4	4.79	4.78	27.0	55	1.84	12.9	Hard, crystalline, taste good, colour brilliant golden
3	Sodium carbonate	81.2	4.76	5.50	24.7	85	2.15	13.7	Hard, crystalline, taste good, colour golden yellow
4	Sodium carbonate with bhindi mucilage	80.4	4.27	5.48	24.5	90	2.61	10.8	Hard, crystalline, taste good, colour golden yellow
5	Sodium bicarbonate	80.4	4.77	5.24	21.3	90	2.07	13.5	Hard, crystalline, taste good, colour golden yellow
6	Sodium bicarbonate with bhindi mucilage	80.2	5.24	5.14	20.5	100	2.22	12.3	Hard, crystalline, taste good, colour golden yellow
7	Potassium carbonate	79.6	5.40	5.00	21.4	175	2.00	12.9	Hard, crystalline, taste good, colour red
8	Acetic acid	80.6	4.67	5.24	23.3	130	2.15	13.2	Hard, crystalline, taste good, colour golden yellow
9	Acetic acid with bhindi mucilage	81.0	5.09	5.50	22.2	95	2.82	15.4	Hard, crystalline, taste good, colour golden yellow
10	Citric acid	80.0	4.69	4.26	20.9	120	2.25	12.9	Hard, crystalline, taste good, colour golden yellow

TABLE I—*contd.*

*Showing properties of Co 313 and Co 453 gur prepared by different treatments*

Co 313

Serial Number	Treatment	Sugrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Millier. acid in 100g.	General observations
						N/4 solution			
11	Aluminium sulphate	79.4	5.70	5.58	19.3	200	1.90	12.6	Hard crystalline, taste good, colour red
12	Aluminium sulphate with <i>bhindi</i> mucilage	79.4	5.69	5.96	20.0	130	2.20	15.4	Hard crystalline, taste good, colour red
13	Alum	79.0	5.12	5.40	20.5	150	2.00	12.9	Hard crystalline, taste good, colour red
14	Alum with <i>bhindi</i> mucilage	79.6	5.69	5.56	19.0	135	2.00	14.8	Hard crystalline, taste good, colour red
15	Caustic soda	80.0	5.69	5.04	18.5	145	2.17	15.4	Hard crystalline, taste good, colour red
16	Caustic soda with <i>bhindi</i> mucilage	78.6	5.15	5.84	19.5	155	1.97	13.0	Hard crystalline, taste good, colour red
17	Ferric chloride with <i>bhindi</i> mucilage	80.6	5.12	5.32	22.8	140	2.20	15.4	Hard crystalline, taste good, colour red

Co 453

18	<i>Bhindi</i> mucilage	80.4	6.42	5.16	21.2	200	2.25	14.8	Hard, not quite crystalline, taste good, colour dark chocolate
19	Castor seed extract	80.4	5.31	5.18	22.1	95	2.04	14.8	Hard, fairly crystalline, taste good, colour cream
20	Double super with <i>bhindi</i> mucilage	80.4	5.32	5.66	21.9	165	2.12	14.8	Hard, not quite crystalline, taste good, colour dark red
21	Caustic soda with <i>bhindi</i> mucilage	78.2	5.49	5.16	18.5	240	1.50	15.4	Hard, not quite crystalline, taste fair, colour dark red
22	Sodium carbonate	80.0	4.40	5.06	19.4	185	2.02	15.4	Hard, not quite crystalline, taste good, colour dark red
23	Acetic acid	80.4	5.12	5.64	18.9	200	1.72	14.2	Hard, not quite crystalline, taste good, colour dark red

TABLE II

*Showing a comparison of the properties of gur from different varieties prepared by the castor seed extract and bhindi mucilage treatments : Season 1945-46*

Serial Num-ber.	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc./100g)	Colour reading	Turbi- dity	Milli eq. acid in 100 g	General observations
							N/4 solution			
1	Co 313	<i>Bhindi</i> mucilage	80.6	4.79	5.06	26.8	95	2.00	12.9	Hard, crystalline, taste good, colour, golden yellow
2	Co 313	Castor seed extract	80.4	4.79	4.78	27.0	55	1.84	12.9	Hard, crystalline, taste good, colour brilliant golden
3	Co 453	<i>Bhindi</i> mucilage	80.4	6.42	5.16	21.2	200	2.25	14.8	Hard, not quite crystalline, taste good, colour dark chocolate
4	Co 453	Castor seed extract	80.4	5.31	5.18	22.1	95	2.04	14.8	Hard, fairly crystalline, taste good, colour cream
5	Co 395	<i>Bhindi</i> mucilage	79.4	4.81	5.12	17.5	160	2.23	13.3	Hard, crystalline taste, good, colour deep red
6	Co 395	Castor seed extract	79.8	4.79	4.90	20.8	85	2.00	13.3	Hard, crystalline taste, good, colour pale yellow
7	Co 513	<i>Bhindi</i> mucilage	80.8	4.79	4.96	27.0	100	1.95	13.3	Hard, crystalline, taste good, colour golden yellow
8	Co 513	Castor seed extract	80.6	4.81	5.04	27.5	60	1.90	12.9	Hard, crystalline, taste good, colour brilliant golden
9	B.O. 3	<i>Bhindi</i> mucilage	74.8	5.31	7.92	20.3	150	2.10	13.3	Hard, crystalline, taste good, colour deep red
10	B.O. 3	Castor seed extract	74.8	4.81	5.06	22.7	80	2.02	13.3	Hard, crystalline, taste good, colour pale yellow

TABLE III

*A comparison of the properties of gur from different varieties prepared by the castor seed and groundnut extracts with blindi mucilage treatment : Season 1946-47*

Serial Num-ber.	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading	Turbidity	Milli eq. acid in 100g	General observations
							N/4 solution			
1	Co 313	<i>Blindi</i> mucilage	79.8	5.13	4.70	23.4	97	2.04	13.3	Hard, crystalline, taste good, colour golden yellow
2	Co 313	Castor seed extract	80.2	5.00	4.64	25.1	53	1.85	13.3	Hard, crystalline, taste good, colour brilliant golden
3	Co 313	Groundnut extract	82.6	5.00	3.84	27.3	48	1.97	12.9	Hard, crystalline, taste good, colour brilliant golden
4	Co 383	<i>Blindi</i> mucilage	81.2	6.41	3.10	11.2	160	2.03	14.8	Hard, crystalline, taste good, colour deep red
5	Co 383	Castor seed extract	82.8	7.70	2.80	21.9	90	1.94	14.8	Hard, crystalline, taste good, colour light whitish yellow
6	Co 395	<i>Blindi</i> mucilage	82.0	6.70	3.74	8.0	165	2.04	15.2	Hard, crystalline, taste good, colour deep red
7	Co 395	Castor seed extract	83.0	5.92	3.54	16.8	97	1.95	14.8	Hard, crystalline, taste good, colour pale yellow
8	Co 453	<i>Blindi</i> mucilage	77.0	10.27	6.54	11.8	260	2.17	16.8	Hard, not quite crystalline, taste good, colour dark chocolate.
9	Co 453	Castor seed extract	81.6	7.33	5.86	19.5	90	2.02	14.8	Hard, crystalline, taste good, colour light cream

TABLE III—contd.

*A comparison of the properties of gur from different varieties prepared by the castor seed and groundnut extracts bindi with mucilage treatment : Season 1946-47—contd.*

Serial Num- ber	Variety	Treatment	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc) (100g)	Colour reading	Turbi- dity	Millieq. acid in 100g	General observations
							N/4 solution			
10	Co 453	Groundnut extract	81.4	7.00	5.24	19.4	90	1.96	14.8	Hard, crystalline, taste good, colour light cream
11	Co 508	<i>Bhindi</i> mucilage	78.0	5.50	5.60	18.1	100	2.00	13.8	Hard, crystalline, taste good, colour golden yellow
12	Co 508	Castor seed extract	78.2	5.30	4.00	21.5	56	1.91	12.5	Hard, crystalline, taste good, colour brilliant golden
13	Co 508	Groundnut extract	78.6	5.13	4.70	24.4	50	1.92	12.5	Hard, crystalline, taste good, colour brilliant golden
14	Co 513	<i>Bhindi</i> mucilage	77.0	5.30	5.04	23.1	96	2.05	12.5	Hard, crystalline, taste good, colour golden yellow
15	Co 513	Castor seed extract	80.2	5.00	5.30	24.8	55	1.90	12.9	Hard, crystalline, taste good, colour brilliant golden
16	Co 513	Groundnut extract	77.0	5.30	5.68	23.6	50	1.90	12.9	Hard, crystalline, taste good, colour brilliant golden
17	B.O. 3	<i>Bhindi</i> mucilage	79.2	8.56	4.98	9.1	152	1.97	15.8	Hard, crystalline, taste good, colour deep red
18	B.O. 3	Castor seed extract	79.2	6.41	2.90	18.0	84	1.90	14.8	Hard, crystalline, taste good, colour pale yellow
19	B.O. 3	Groundnut extract	80.2	6.16	3.18	19.2	80	1.93	14.4	Hard, crystalline, taste good, colour whitish yellow

March, 1949]

## STUDIES IN THE CLARIFICATION OF SUGARCANE JUICE

20	B.O. 10	<i>Bhindi</i> mucilage .	79.4	7.33	2.86	7.1	180	2.00	16.4	Hard, crystalline, taste good, colour deep red
21	B.O. 10	Castor seed extract	81.2	5.92	3.10	21.0	100	1.95	14.8	Hard, crystalline, taste good, colour pale yellow
22	B.O. 11	<i>Bhindi</i> mucilage .	82.8	6.70	4.22	15.9	175	2.00	14.8	Hard, crystalline, taste good, colour deep red
23	B.O. 11	Castor seed extract	82.4	5.31	2.96	31.4	100	1.90	14.8	Hard, crystalline, taste good, colour pale yellow
24	B.O. 15	<i>Bhindi</i> mucilage .	78.0	7.00	4.54	16.9	185	2.05	15.3	Hard, crystalline, taste good, colour deep red
25	B.O. 15	Castor seed extract	81.2	4.40	4.50	23.6	105	1.90	14.8	Hard, crystalline, taste good, colour pale yellow
26	B.O. 21	<i>Bhindi</i> mucilage .	80.8	5.92	4.90	16.6	180	2.00	15.8	Hard, crystalline, taste good, colour deep red
27	B.O. 21	Castor seed extract	82.0	5.70	3.80	21.8	100	1.94	15.3	Hard, crystalline, taste good, colour pale yellow
28	B.O. 24	<i>Bhindi</i> mucilage .	81.2	6.16	4.50	9.6	178	2.03	15.8	Hard, crystalline, taste good, colour deep red
29	B.O. 24	Castor seed extract	81.0	5.70	4.64	17.9	97	1.96	13.3	Hard, crystalline, taste good, colour pale yellow
30	B.O. 24	Groundnut extract	82.6	5.13	4.14	28.5	93	1.95	13.8	Hard, crystalline, taste good, colour whitish yellow

TABLE IV  
*A comparison of the properties of gurr from different varieties prepared by the castor seed  
 and groundnut extracts with bhindi mucilage treatment : Season 1947-48*

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Turbidity		Milli eq. acid in 100g	Ash per cent	Nett Rendement	General observations
							Colour reading	N/4 solutions				
1	Co 313	Bhindi mucilage	79.6	4.40	5.16	23.8	120	2.00	14.3	1.84	68.8	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	78.8	4.52	4.88	24.0	75	1.78	14.8	1.86	67.8	Hard, crystalline, taste good, colour golden
		Groundnut extract	79.8	3.08	4.84	24.6	70	1.71	13.8	1.86	70.2	Hard, crystalline, taste good, colour golden
1	Co 513	Bhindi mucilage	80.0	5.50	4.90	24.8	135	1.96	14.8	1.92	67.8	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	84.4	5.13	4.80	25.9	65	1.84	13.3	1.90	73.6	Hard, crystalline, taste good, colour golden
		Groundnut extract	85.0	4.52	5.00	26.3	70	1.88	12.3	1.90	73.8	Hard, crystalline, taste good, colour bright golden
1	Co 453	Bhindi mucilage	78.4	3.85	5.80	14.3	350	2.14	16.3	2.84	64.6	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	85.6	3.58	4.44	17.8	140	1.85	13.8	2.88	71.9	Hard, crystalline, taste good, colour cream
		Groundnut extract	83.8	3.52	4.14	17.5	140	1.85	14.8	2.86	70.3	Hard, crystalline, taste good, colour cream
1	Co 383	Bhindi mucilage	76.8	7.70	5.04	16.2	275	2.18	15.8	2.70	59.7	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	78.0	7.35	4.16	16.3	135	1.85	15.3	2.70	61.2	Hard, crystalline, taste good, colour light yellow
		Groundnut extract	78.8	5.50	4.10	16.3	140	1.82	15.8	2.66	64.0	Hard, crystalline, taste good, colour light yellow
1	Co 313	Bhindi mucilage	81.2	3.20	4.20	24.2	110	2.00	13.8	2.06	70.8	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	81.0	3.34	4.12	27.1	60	1.83	13.8	1.98	70.7	Hard, crystalline, taste good, colour golden
		Groundnut extract	80.8	3.14	4.10	27.2	60	1.83	13.8	2.04	70.7	Hard, crystalline, taste good, colour bright golden

2	Co 513	<i>Bhindi</i> mudlage	50.0	5.13	5.04	20.6	125	2.00	13.8	2.12	67.5	Hard, crystalline, taste good, colour golden
		Castor seed extract	79.8	4.40	4.14	21.8	70	1.73	14.3	2.10	68.1	Hard, crystalline, taste good, colour bright
		Groundnut extract	80.4	4.90	4.10	24.7	75	1.73	13.3	2.12	68.0	Hard, crystalline, taste good, colour bright, golden
2	Co 453	<i>Bhindi</i> mudlage	80.4	4.81	4.20	11.2	300	2.33	13.8	2.52	67.4	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	80.2	4.16	5.00	18.8	140	1.92	13.3	2.56	66.2	Hard, crystalline taste good, colour cream
		Groundnut extract	80.2	4.67	5.00	20.0	125	1.92	13.8	2.54	66.3	Hard, crystalline, taste good, colour cream
2	Co 333	<i>Bhindi</i> mudlage	78.6	4.99	4.06	13.8	215	2.06	14.3	2.44	66.0	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	79.0	4.52	4.10	19.6	125	1.88	13.8	2.46	66.3	Hard, crystalline taste good, colour light yellow
		Groundnut extract	79.8	4.90	4.14	19.0	115	1.82	14.3	2.44	67.1	Hard, crystalline, taste good, colour, light yellow
3	Co 313	<i>Bhindi</i> mudlage	79.8	2.65	4.66	23.0	100	1.98	14.8	2.02	70.1	Hard, crystalline, taste good, colour golden
		Castor seed extract	80.2	2.56	4.80	25.8	55	1.72	15.3	1.98	70.7	Hard, crystalline, taste good, colour, bright yellow
		Groundnut extract	79.6	2.65	4.94	27.3	60	1.97	15.3	2.04	69.8	Hard, crystalline, taste good, colour bright golden
3	Co 513	<i>Bhindi</i> mudlage	80.8	2.44	5.00	19.7	110	1.95	14.3	2.14	70.3	Hard, crystalline, taste good, colour golden
		Castor seed extract	80.6	2.56	4.06	22.9	60	1.97	13.3	2.12	70.6	Hard, crystalline taste good, colour bright golden
		Groundnut extract	81.0	2.48	4.10	23.0	60	1.73	13.3	2.14	71.0	Hard, crystalline, taste good, colour bright golden
3	Co 453	<i>Bhindi</i> mudlage	74.6	3.01	5.06	10.7	315	2.12	15.8	3.06	69.9	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	74.4	2.99	5.10	17.0	150	2.90	14.3	3.02	69.8	Hard, crystalline, taste good, colour cream
		Groundnut extract	75.0	3.03	4.24	17.3	120	1.83	13.8	3.10	61.1	Hard, crystalline, taste good, colour cream

TABLE IV

*A comparison of the properties of gur from different varieties prepared by the castor seed and groundnut extracts with bhindi mucilage treatment : Season 1947-48—contd.*

Repl- cation No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Mols- ture per cent	Pore space (cc/100g)	Colour reading N/4 solutions	Turbid- ity	MIH eq. acid in 100 g	Ash per cent	Nett Recov- ment	General observations
3	Co 383	Bhindi mucilage	74.2	2.83	5.00	15.3	250	2.10	15.3	2.42	62.9	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	74.8	2.86	5.02	10.0	160	1.87	15.3	2.46	63.3	Hard, crystalline, taste good, colour light
		Groundnut extract	74.2	2.70	4.98	20.0	153	1.87	14.8	2.38	63.2	Hard, crystalline, taste good, colour light yellow
4	Co 313	Bhindi mucilage	80.4	2.44	4.56	18.7	115	2.04	15.8	1.94	71.2	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	80.6	2.29	4.66	20.5	60	1.67	14.3	1.88	71.7	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	80.2	2.33	4.10	20.1	60	1.75	14.8	1.98	70.9	Hard, crystalline, taste good, colour bright golden
4	Co 513	Bhindi mucilage	79.6	2.44	5.00	27.2	110	1.95	16.8	2.24	69.3	Hard, crystalline, taste good, colour golden yellow (dull)
		Castor seed extract	79.6	2.48	5.08	28.0	65	1.84	14.3	2.28	69.1	Hard, crystalline, taste good, colour bright golden
		Groundnut extract	79.6	2.35	4.08	27.2	60	1.75	14.3	2.24	69.4	Hard, crystalline, taste good, colour bright golden
4	Co 453	Bhindi mucilage	79.0	3.27	5.00	15.8	300	2.18	17.8	2.74	66.1	Hard, crystalline, taste good, colour dark chocolate
		Castor seed extract	79.4	3.20	5.00	22.0	180	1.90	16.3	2.80	66.4	Hard, crystalline, taste good, colour cream
		Groundnut extract	79.6	3.08	5.10	22.6	135	1.88	16.3	2.74	66.9	Hard, crystalline, taste good, colour cream
Co 383		Bhindi mucilage	73.0	3.67	5.02	18.0	270	2.15	15.8	2.38	61.0	Hard, crystalline, taste good, colour chocolate
		Castor seed extract	73.2	3.85	4.01	25.0	145	1.89	15.8	2.26	61.4	Hard, crystalline, taste good, colour light yellow
		Groundnut extract	73.0	3.42	4.06	22.1	125	1.83	14.8	2.40	61.8	Hard, crystalline, taste good, colour light yellow

TABLE V  
A comparison of the properties of gur prepared from immature canes by the castor seed  
and groundnut extracts with bhindi mucilage treatment: Season 1947-48

Repl. cation No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Mois- ture per cent	Pore space (cc/100g)	Colour reading	Turbid- ity	Milli eq. acid in 100g.	Ash per cent	Nett Rende- ment	General observations
1	Co 313	Bhindi mucilage	68.6	6.16	7.50	15.0	200	2.18	25.0	3.24	51.1	Hard, not quite crystal- line, taste good, colour dark red.
		Castor seed extract	69.0	5.70	5.70	16.9	120	1.87	17.3	3.26	51.9	Hard, crystalline, taste good, colour brownish yellow.
		Groundnut extract	69.2	5.70	5.00	17.7	110	1.82	17.3	3.24	52.1	Hard, crystalline, taste good, colour brownish yellow.
2	Co 313	Bhindi mucilage	69.8	5.70	7.46	13.2	225	2.13	25.5	3.26	51.7	Hard, not quite crystal- line, taste good, colour dark red.
		Castor seed extract	69.6	5.50	4.94	17.0	110	1.82	16.3	3.26	52.7	Hard, crystalline, taste good, colour brownish yellow.
		Groundnut extract	69.4	5.31	5.00	16.3	105	1.81	16.8	3.28	52.6	Hard, crystalline, taste good, colour brownish yellow.
3	Co 313	Bhindi mucilage	69.0	5.70	6.64	12.5	220	2.16	22.0	3.26	51.9	Hard, not quite crystal- line, taste good, colour dark red.
		Castor seed extract	69.6	5.31	5.72	19.8	100	1.85	15.8	3.24	53.0	Hard, crystalline, taste good, colour brownish yellow.
		Groundnut extract	69.8	5.31	5.74	20.0	105	1.81	16.8	3.24	53.2	Hard, crystalline, taste good, colour brownish yellow.
4	Co 313	Bhindi mucilage	71.0	5.31	6.60	13.7	215	2.00	23.0	3.22	54.4	Hard, not quite crystal- line, taste good, colour dark red.
		Castor seed extract	69.8	4.97	4.90	20.2	100	1.98	16.3	3.20	53.6	Hard, crystalline, taste good, colour brownish yellow.
		Groundnut extract	69.6	5.13	5.74	20.9	100	1.90	17.3	3.24	53.1	Hard, crystalline, taste good, colour brownish yellow.
5	Co 313	Bhindi mucilage	70.4	5.50	6.60	13.0	200	2.25	21.0	3.14	53.9	Hard, not quite crystal- line, taste good, colour dark red.
		Castor seed extract	70.0	5.13	5.00	19.5	105	1.90	15.3	3.14	53.9	Hard, crystalline, taste good, colour brownish yellow.
		Groundnut extract	70.0	5.13	5.00	20.4	105	1.90	15.8	3.12	53.9	Hard, crystalline, taste good, colour brownish yellow.

TABLE VI

*A comparison of the properties of gur from water logged canes prepared by the castor seed and groundnut extract with blindi mucilage treatment : Season 1947-48*

Replication No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Moisture per cent	Pore space (cc/100g)	Colour reading N/4 solutions	Turbidity	Mill eq. acid in 100g.	Ash per cent	Nett Rancidment	General observations
1	Mixed (Same juice for all treatments)	<i>Blindi</i> mucilage	72.4	5.70	6.00	10.5	330	1.98	24.5	3.04	56.1	Not quite hard on crystalline taste indifferent, colour very dark chocolate
		Castor seed extract	72.6	5.70	5.84	14.3	105	1.94	21.0	3.02	56.3	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	72.4	5.50	5.90	13.1	168	1.96	20.5	3.08	56.1	Hard, crystalline, taste good, colour yellowish brown
		<i>Blindi</i> mucilage	74.0	6.16	5.02	9.8	325	1.97	22.0	2.90	57.7	Not quite hard on crystalline taste indifferent, colour very dark chocolate
2	do	Castor seed extract	74.6	6.42	4.04	15.0	160	1.87	20.0	2.92	58.0	Hard crystalline, taste good, colour yellowish brown
		Groundnut extract	74.4	6.16	5.88	14.8	160	1.87	19.5	2.90	58.1	Hard crystalline, taste good, colour yellowish brown
		<i>Blindi</i> mucilage	75.0	6.16	5.80	12.7	300	2.03	25.0	3.28	57.4	Not quite hard on crystalline taste indifferent, colour very dark chocolate
		Castor seed extract	75.0	6.42	5.00	14.9	130	1.92	19.5	3.30	57.0	Hard, crystalline, taste good, colour yellowish brown
3	do	Groundnut extract	74.8	5.92	5.92	15.8	118	1.90	19.5	3.40	57.0	Hard, crystalline, taste good, colour yellowish brown

TABLE VII  
A comparison of the properties of gurr prepared by the castor seed, groundnut, deola and falsa extract treatments :  
Season 1947-48

Repl- cation No.	Variety	Treatments	Sucrose per cent	Glucose per cent	Mols- ture per cent	Pore space (cc/100g)	Turbid- ity		Millieq. acid in 100g	Ash per cent	Nett Rende- ment	General observations
							Colour reading	N/4 solutions				
1	Co 513	Deola mucilage	80.2	3.58	5.00	25.0	95	2.00	13.8	2.06	68.0	Hard, crystalline, taste good, colour dull yellow, taste good,
		Falsa extract	78.4	4.40	4.94	24.0	130	2.00	13.8	2.02	66.4	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	80.2	3.42	4.14	25.1	62	1.77	14.3	2.06	60.9	Hard, crystalline, taste good, colour bright golden
2	Co 513	Deola mucilage	79.6	4.81	4.10	23.7	100	2.15	12.8	2.12	68.1	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	78.6	5.13	4.96	24.5	145	1.89	14.3	2.04	66.5	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	79.4	3.99	4.13	25.8	65	1.76	12.3	2.10	67.9	Hard, crystalline, taste good, colour bright golden
3	Co 513	Deola mucilage	80.8	4.52	4.88	22.0	100	2.00	14.3	1.94	67.5	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	80.0	4.40	4.90	21.6	150	2.00	13.8	1.98	68.7	Hard, crystalline, taste good, colour yellowish brown
		Castor seed extract	80.4	4.27	4.06	23.2	60	1.92	13.3	1.92	69.4	Hard, crystalline, taste good, colour bright golden
1(a)	Co 513	Deola mucilage	80.0	4.05	4.10	24.3	100	2.00	14.8	2.04	68.8	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	80.0	4.16	4.30	21.3	130	2.00	14.3	2.04	67.9	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	80.8	4.05	4.20	24.5	60	1.67	13.3	2.06	69.4	Hard, crystalline, taste good, colour bright golden
2(a)	Co 513	Deola mucilage	79.0	4.05	5.02	20.1	90	2.02	14.8	1.98	67.1	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	79.0	4.05	5.00	19.1	125	2.08	14.8	2.02	66.9	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	79.8	4.05	5.00	22.0	58	1.89	14.3	2.02	67.7	Hard, crystalline, taste good, colour bright golden
3(a)	Co 513	Deola mucilage	78.2	4.16	4.10	23.7	97	2.01	14.3	1.96	67.2	Hard, crystalline, taste good, colour dull yellow
		Falsa extract	77.4	4.05	4.16	21.0	130	2.11	14.3	1.98	66.4	Hard, crystalline, taste good, colour yellowish brown
		Groundnut extract	78.2	3.85	4.10	25.9	65	1.84	14.3	1.98	67.4	Hard, crystalline, taste good, colour bright golden

TABLE VIII

*A statistical comparison of the properties of gur prepared by the blindi mucilage, castor seed extract and groundnut extract treatments. : Season 1947-48*

Treatments Characters	Blindi mucilage (B)	Castorseed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	78.53	79.35	79.43	CD at 5 per cent = 1.50; at 5 per cent: $\overline{GCB}$ ; non-significant
Glucose	3.90	3.74	3.53	CD at 5 per cent = 0.54; at 5 per cent: $\overline{BCG}$ ; non-significant
Moisture	4.80	4.55	4.44	CD at 5 per cent = 0.30; at 5 per cent: $\overline{BCG}$ ; non-significant
Pore space	18.39	21.84	22.00	CD at 5 per cent = 1.87; CD at 1 per cent = 2.52; at 5 per cent: $\overline{GCB}$ ; at 1 per cent: $\overline{GCB}$ ; highly significant
Colour (N/4 solution)	200	104	98	CD at 5 per cent = 9.4; CD at 1 per cent = 12.6; at 5 per cent: $\overline{BCG}$ ; at 1 per cent $\overline{BCG}$ ; highly significant
Turbidity (N/4 solution)	2.07	1.83	1.81	CD at 5 per cent = 0.04; CD at 1 per cent = 0.06; at 5 per cent: $\overline{BCG}$ ; at 1 per cent: $\overline{BCG}$ ; highly significant
Acidity	15.18	14.46	14.27	CD at 5 per cent = 0.52; at 5 per cent: $\overline{BCG}$ ; non-significant
Ash	2.34	2.33	2.33	CD at 5 per cent = 0.11; at 5 per cent: $\overline{B(GC)}$ ; non-significant
Nett Rendement	66.6	67.4	67.8	CD at 5 per cent: 1.81; at 5 per cent: $\overline{GCB}$ ; non-significant

TABLE IX

*A statistical comparison of the properties of gur prepared from immature canes by the blindi mucilage, castor seed extract and groundnut extract treatments :  
Season 1947-48*

Treatments Characters	<i>Bhindi</i> mucilage (B)	Castor seed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	69.6	69.6	69.6	CD at 5 per cent = 0.75; at 5 per cent: (BCG); non-significant
Glucose	5.67	5.32	5.32	CD at 5 per cent = 0.11; CD at 1 per cent = 0.16; at 5 per cent: BCG; at 1 per cent: BCG; highly significant
Moisture	6.96	5.25	5.30	CD at 5 per cent = 0.67; CD at 1 per cent = 0.97; at 5 per cent: BCG at 1 per cent: BCG; highly significant
Pore space	13.5	18.7	19.1	CD at 5 per cent = 2.87; CD at 1 per cent = 4.17 at 5 per cent: GCB; at 1 per cent: GCB; highly significant
Colour (N/4 solution)	212	107	105	CD at 5 per cent = 18.88; CD at 1 per cent: 27.47; at 5 per cent: BCG at 1 per cent: BCG; highly significant
Turbidity (N/4 solution)	2.16	1.88	1.85	CD at 5 per cent = 0.06; CD at 1 per cent = 0.11; at 5 per cent: BCG; at 1 per cent: BCG; highly significant
Acidity	22.1	16.2	16.8	CD at 5 per cent = 0.57; CD at 1 per cent = 0.83; at 5 per cent: BGC; at 1 per cent: BGC; highly significant
Ash	3.22	3.22	3.22	CD at 5 per cent = 0.03; at 5 per cent: (BCG); non-significant
Nett Rendements	52.6	53.0	53.0	CD at 5 per cent: 0.81; at 5 per cent: GCB; non-significant

TABLE X

*A statistical comparison of the properties of gur prepared from water logged canes by the blindi mucilage, castor seed extract and groundnut extract treatments :  
Season 1947-48*

Treatments Characters	Blindi mucilage (B)	Castor seed extract (C)	Groundnut extract (G)	Conclusions
Sucrose	73.8	74.1	73.9	CD at 5 per cent = 0.39; at 5 per cent: $\overline{CGB}$ ; non-significant
Glucose	6.01	6.18	5.86	CD at 5 per cent = 0.24; at 5 per cent: $\overline{CBG}$ ; significant
Moisture	5.61	5.26	5.90	CD at 5 per cent = 0.75; at 5 per cent: $\overline{GBC}$ ; non-significant
Pore space	11.0	14.7	14.6	CD at 5 per cent = 2.065; at 5 per cent: $\overline{CGB}$ ; significant
Colour (N/4 solution)	318	152	145	CD at 5 per cent = 10.13; at 1 per cent = 16.80; at 5 per cent: $\overline{BCG}$ ; at 1 per cent: $\overline{BCG}$ ; highly significant
Turbidity (N/4 solution)	1.99	1.91	1.91	CD at 5 per cent = 0.07; at 5 per cent: $\overline{B(CG)}$ ; significant
Acidity	23.2	20.2	19.8	CD at 5 per cent = 1.11; CD at 1 per cent = 1.84; at 5 per cent: $\overline{BCG}$ ; at 1 per cent: $\overline{BCG}$ ; highly significant
Ash	3.07	3.08	3.13	CD at 5 per cent = 0.09; at 5 per cent: $\overline{GCB}$ ; non-significant
Nett Rendement	57.1	57.1	57.1	CD at 5 per cent = 0.50; at 5 per cent: $\overline{(BCG)}$ ; non-significant

TABLE XI

*A statistical comparison of the properties of gur prepared by the deola, falsa bark and castor seed extract treatments : Season 1947-48*

Treatments Characters	Deola mucilage (D)	Falsa bark mucilage (F)	Castor seed extract (C)	Conclusions
Sucrose	81.2	79.0	80.0	CD at 5 per cent = 0.83; at 5 per cent: $\overline{DCF}$ ; significant
Glucose	4.30	4.64	3.89	CD at 5 per cent = 0.75; at 5 per cent: $\overline{FDC}$ ; non-significant
Moisture	4.66	4.93	4.13	CD at 5 per cent = 0.69; at 5 per cent: $\overline{FDC}$ ; non-significant
Pore space	23.6	23.7	24.7	CD at 5 per cent = 1.29; at 5 per cent: $\overline{CFD}$ ; non-significant
Colour (N/4 solution)	98	142	62	CD at 5 per cent = 12.83; at 1 per cent = 21.27; at 5 per cent: $\overline{FDC}$ ; at 1 per cent: $\overline{FDC}$ ; highly significant
Turbidity (N/4 solution)	2.05	1.96	1.82	CD at 5 per cent = 0.21; at 5 per cent: $\overline{DFC}$ ; non-significant
Acidity	13.6	14.0	13.3	CD at 5 per cent = 1.64; at 5 per cent: $\overline{FDC}$ ; non-significant
Ash	2.04	2.01	2.03	CD at 5 per cent = 0.082; at 5 per cent: $\overline{DCF}$ ; non-significant
Nett Rendement	67.9	67.2	68.1	CD at 5 per cent = 2.11; at 5 per cent: $\overline{CDF}$ ; non-significant

TABLE XII

*A statistical comparison of the properties of gur prepared by the deola, falsa bark and groundnut extract treatments : Season 1947-48*

Treatments Characters	<i>Deola</i> mucilage (D)	<i>Falsa bark</i> mucilage (F)	Groundnut extract (G)	Conclusions
Sucrose	79.1	78.8	79.6	CD at 5 per cent = 0.58; at 5 per cent: $\overline{\text{GDF}}$ ; significant
Glucose	4.09	4.09	3.98	CD at 5 per cent = 0.22; at 5 per cent: $(\overline{\text{DF}})\text{G}$ ; non-significant
Moisture	4.41	4.69	4.43	CD at 5 per cent = 0.56; at 5 per cent: $\overline{\text{FGD}}$ ; non-significant
Pore space	22.7	20.5	24.1	CD at 5 per cent = 1.72; at 5 per cent: $\overline{\text{GDF}}$ ; significant
Colour (N/4 solution)	96	128	61	CD at 5 per cent = 5.32; CD at 1 per cent = 9.82; at 5 per cent: $\overline{\text{FDG}}$ ; at 1 per cent: $\overline{\text{FDG}}$ ; highly significant
Turbidity (N/4 solution)	2.01	2.06	1.80	CD at 5 per cent = 0.125; at 1 per cent = 0.21; at 5 per cent: $\overline{\text{FDG}}$ ; at 1 per cent: $\overline{\text{FDG}}$ ; highly significant
Acidity	14.6	14.5	14.0	CD at 5 per cent = 0.89; at 5 per cent: $\overline{\text{DFG}}$ ; non-significant
Ash	1.99	2.02	2.02	CD at 5 per cent = 0.02; at 5 per cent: $(\overline{\text{FG}})\text{D}$ ; significant
Nett Rendement	67.7	67.1	68.2	CD at 5 per cent = 0.55; at 5 per cent: $\overline{\text{GDF}}$ ; significant

TABLE XIII

*A comparison of chemical characteristics at different extracts*

Extract	Crude* pro- teins	True† pro- teins	True pro- teins per cent crude pro- teins	Ash	Soluble SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO
<i>Bhindi</i> . . .	79	13	16.4	92	16	2	4	3	Traces
<i>Deola</i> . . .	316	61	19.3	120	12	3	8	2	Traces
<i>Falsa</i> . . .	97	22	22.5	134	8	1	3	4	Traces
Castor seed . .	586	569	97.1	122	18	8	7	Traces	Traces
Groundnut . .	1164	892	76.6	118	22	9	39	Traces	Traces

\* Determined by the usual Kjeldahl method

† Precipitation with Stutzer's (copper hydroxide) reagent and then determined by Kjeldahl method

TABLE XIV

*Showing yields of gur on juice*

Month	Gur per cent juice (average)		
	Castor seed extract clari- fication	<i>Bhindi</i> mucilage clari- fication	Groundnut extract clari- fication
November . . . . .	15.8	15.3	15.3
December . . . . .	16.7	17.0	16.6
January . . . . .	17.4	17.3	16.7
February . . . . .	17.7	17.2	16.9
March . . . . .	18.0	17.6	19.1
Seasonal average . . . . .	17.1	16.9	16.9



# INVESTIGATIONS ON THE ALKALINITY AND SALTISHNESS IN *GUR* MADE FROM COIMBATORE SUGARCANE VARIETIES\*

By P. G. KRISHNA, B. Sc., Ph. D. (CORNELL), Agricultural Chemist to H. E. H. the Nizam's Government, Hyderabad-Deccan

(Received for publication on 23rd January 1948)

PRIOR to 1930, sugarcane cultivation in Hyderabad-Deccan was restricted to isolated areas under wells and tanks. It was mostly for the manufacture of *gur* (jaggery) and partly for chewing, both to meet local demand only. The local variety of sugarcane called '*desi*' was commonly grown. It was crimson-striped or white, medium thick and soft. The cultivation used to be in flat beds. As the plants were lodging they had to be supported. Expenses in this direction were enormous. Water-logging wherever it occurred adversely affected the crop. Damage due to pigs was considerable. In view of these difficulties, there was a search by the Department of Agriculture for a non-lodging, hardy sugarcane which was at the same time a high yielder. Coimbatore 213 was found to be quite satisfactory. So, around 1930, this variety was introduced all over the State along with the new method of trench cultivation. Soon it became popular and area under sugarcane began to spread rapidly. However, shortly afterwards, complaints began to be received from project areas of Nizamasagar, Vaira and Paler that *gur* made from this new variety (Co. 213) was saltish.

It was, therefore, decided that this problem should be fully investigated

## LITERATURE

The mineral composition of sugarcane juice with particular reference to the soils and irrigation waters has received the attention of several workers. Varahalu [1935-36] observed that saline soils, dry conditions and brackish water produce sugarcane juice with a large amount of non-sugar organic matter. Lander and Ramji Narain [1939] noticed that soils with low exchangeable calcium produce cane of abnormally high mineral content. Mc Kaig and Fort [1938] have attributed differences in quality of juice to the types of soils used by them. Swadi [1919] stated that grey soils, and brackish water containing too much of magnesium salts particularly chlorides, are responsible for the bad keeping quality and hardness of *gur*. He noticed that the salinity was distinctly marked even to the taste. It was just a general reference.

Sanyal [1928], Varahalu [1936], and Bhushanam [1945] have indicated that the application of inorganic fertilizers, especially nitrogenous, produces *gur* of low keeping quality. It is not so with organic fertilizers. Krishnamurthy Rao [1919] showed that the chlorine absorbed by canes from soil and irrigation waters was responsible for production of jaggery of bad quality. Norris, Vishwanath and Govinda Nayar [1922] attributed the bad keeping quality of jaggery to its calcium and magnesium chloride contents and stated that it is not chlorine or sodium chloride that impair the keeping quality of juice but highly deliquescent compounds of chlorine.

\* Paper contributed for reading in the Section of Agricultural Science, Indian Science Congress Association, 35th Congress, Patna, January, 1948

Thus, almost all the earlier workers have particularly dealt with factors governing the keeping quality of *gur* but not its taste. Swadi [1919] seems to be the only one who had noticed saltishness in *gur* but his was merely a passing reference.

#### OBJECT OF INVESTIGATION

Keeping in view the important findings of these workers regarding the effect of soils, irrigation waters, and fertilizers, the author has attempted in the present investigation to find out the cause of saltishness in *gur*, whether it is dependent on total salt content or any particular item and what the correlation is. So far, nobody seems to have thought that ratooning introduces some changes as well. The author has attempted to deal with that aspect also. Thirdly, keeping in view the general observation of Krishnamurthy Rao [1919] that thick canes absorb less chlorine than thin ones, the author has made an elaborate and systematic study of the differential absorption of sugarcane varieties.

#### EXPERIMENTAL WORK

*Gur* samples made from Co. 213 and from Local cane were obtained from many parts of the State for analysis. *Gur* samples from several Coimbatore sugarcane varieties grown on different experiment stations were also obtained. Their colour, hardness and taste were noted and then the percentages of moisture, sucrose, glucose, ash, alkalinity, chlorine and sulphate determined by analysis. Some of the soils and irrigation waters used for growing sugarcanes were also analyzed for the water-soluble salts. In all about 400 samples were analyzed for various items during the seven years of investigation.

#### *Alkalinity in gur*

Alkalinity is expressed in cubic centimeters of normal acid required to neutralize the ash obtained from 100 grammes of *gur*. Table I indicates that in the case of local sugarcanes alkalinity varied from 3.9 to 8.8. Only in one instance it was 17.5 and it is quite possible that this high alkalinity is due to the presence of alkaline salts in wood ash used as a clarifying agent in the manufacture of *gur*. None of the *gur* samples made from local cane was saltish. All these samples were obtained from old sugarcane areas in different parts of the State.

Of the *gur* samples obtained from Himayatsagar farm those of Co. 213, 223 and 290 were saltish while varieties such as Hebbal Mysore, P. O. J., E. K. and Fiji B were not. The alkalinity in the ash of *gur* of Co. 213, 223 and 290 was also quite high varying considerably from 3 to 12. That such varietal differences may be expected was indicated by Krishnamurthy Rao [1919] for thick and thin canes.

Of the samples obtained from Rudrur farm, Nizamabad district, only 2 out of 17 were saltish and the total alkalinity was 3 to 9 which is somewhat lower than the Himayatsagar samples. Alkalinity was about the same in *gur* made from Co. 213 cultivated in both the clay loams (*regur*) and red sandy loams (*chalka*). It may be noted that on the Himayatsagar and Rudrur farm soils sugarcane crops were not previously cultivated.

Amongst the Parbhani samples, only one (*i.e.*, Co. 290) was saltish. Alkalinity in them was as low as 3 to 6 which is considerably less than in the samples from the other two farms.

The sugarcane soils at Himayatsagar vary from light to heavy clay loams derived from granitoid gneissic complex while those of Rudrur vary from red sandy loams to clay loams being of a mixed origin in as much as they are derived from both basalt and granitoid gneissic as the farm is located at the base of a basalt hill which is an intrusion in the granitoid gneissic area. The sugarcane soils of Parbhani are clay loams derived from basalt (trap).

From the foregoing evidence, it seems that the type of soil governs to some extent the composition of juice (as reflected in *gur*) obtained from sugarcanes growing therein. This is in agreement with the observation of Mc Kaig and Fort [1938].

From Table I, it seems that *gur* made from Coimbatore and other sugarcane varieties cultivated in different areas has a varying alkaline content. This is further borne out by the data for three successive years in Table II in which canes cultivated at Himayatsagar farm, show a higher alkalinity in *gur* as compared to the same canes grown at Rudrur farm. Therefore, any variation in alkalinity of *gur* may not be a varietal characteristic. The cause may be due to factors such as climate, soil, irrigation water, and manurial treatments. Bhushanam [1945], Sanyal [1928], Varahalu [1935-36], and Wilcox [1946] have shown that the manurial treatments have a definite effect on the composition of juice. But here, the manurial treatments at both the farms were about the same and consisted of green manuring and an application of 100 to 150 pounds of nitrogen per acre in the form of castor and groundnut cakes. As such, the variation in alkalinity may be due to the other three factors.

An analysis of the samples of sugarcane soils and irrigation waters at both the Himayatsagar and Rudrur farms (Table III) indicates that the water soluble salt content of the soils at both the farms is about the same at the time of sampling, while that for irrigation waters is considerably higher at Himayatsagar. If these were considered along with climatic factors, especially the annual rainfall, the cause for lower alkali salt content of *gur* samples from Rudrur farm becomes evident. The annual rainfall on Himayatsagar farm varies from 20 to 25 inches while that on Rudrur farm from 35 to 45 inches. Although the total water soluble salt content of soils on both farms at the time of sampling (*i. e.*, in summer months) is about the same, this is likely to vary a great deal during the monsoon months. At Rudrur, with almost twice the amount of rainfall, it is bound to be considerably lower as we know that the chlorides are easily translocated, and the other salts to a lesser extent, by washing or leaching.

Another important difference is in the number of irrigations. The sugarcane crop at Himayatsagar has to be irrigated much more than at Rudrur; and as the quality of the waters differs, the effect of frequent irrigations as at Himayatsagar would be to add larger amounts of alkali salts to the soil, which are absorbed by the sugarcane crop, and which in turn increase the alkalinity in *gur*. Hence, it may be

deduced, that the composition of the soil and irrigation waters used for growing sugarcanes is greatly reflected in the alkalinity of *gur* obtained therefrom.

A similar but somewhat modified relationship has been indicated by some other workers [Holmes, 1938 ; Lander and Chopra 1942 ; Lander and Ramji Narain, 1936, 1939 ; Norris, Viswanath and Govindanayar, 1922, 1924 ; Sanyal, 1928]. It was in connection with the keeping quality and hardness of *gur*, which are stated to be dependent on the salt content of sugarcane juice, that is controlled and modified by the mineral composition of the soil and irrigation waters.

#### *Effect of ratooning on the alkalinity in gur*

In Table IV are given the data for alkalinity in *gur* made from Coimbatore sugarcane varieties 213, 223, 281 and 290, both from plant (new crop) and ratoon canes for three successive years. It is seen, that *gur* made from ratoon cane has invariably less alkalinity than that from plant cane of the same variety. This indicates that on continued cane cultivation there is a decrease in the alkaline salt content of *gur*, probably because of the reduction in salt content of the soils as some of the salts are absorbed by the first cane crop, thus leaving less salts for absorption by the succeeding cane crop.

Another noteworthy feature is, that in *gur* made from ratoon canes, a greater number is sweet as compared to *gur* from plant canes of the same variety, excepting in the year 1935 when the rainfall received was one of the lowest on record being only 17.74 inches during the sugarcane season when there was not much difference in this respect.

#### *Relation between total alkalinity in ash of gur and taste*

From a perusal of Tables I, II and V it is seen that there is no relation at all between total alkalinity in ash of *gur* and their taste, as some of the *gur* samples with very low alkalinity are saltish, while some with quite high alkalinity are sweet.

#### *Selective absorption of sugarcane varieties*

In Table V are recorded the total alkalinity in ash of *gur* and taste of *gur* for 20 leading sugarcane varieties which were under trial at Himayatsagar farm for three years. Table VI gives further record of 18 of these varieties for another four years. As pointed above, it is seen that there is no relation between total alkalinity and saltishness. It might however be noted that of these several varieties, some responded quite consistently during all these years, either being always saltish or always sweet. *Gur* of variety Co. 419 was always sweet and of Co. 434, 429 and 509 mostly sweet. Co. 290 and 513 always gave saltish *gur*. In some of the varieties like Co. 408, 421, 423, 520 and 524 the *gur* samples were sweet for about half the replications and saltish for the rest. Co. 301 which has come to lead in the yield of sugarcane during the last four years is similar to Co. 290 in saltishness. Co. 426,

331, 313 and 532 mostly yielded saltish *gur*. Co. 244 seems somewhat better than Co. 301 and 290. The rest of the varieties sometimes yielded sweet *gur* and sometimes saltish and were not consistent. The manifestation of these differences has occurred inspite of the varieties having been planted in a randomized manner. It is likely, therefore, that these varieties are all selective in their absorbing capacity for salts in the soil and irrigation waters, some avoiding some particular salts and others preferring them. As will be seen from the discussion to follow, chlorides which are responsible for saltishness are probably not absorbed to such a great extent by sugarcane varieties always yielding sweet *gur* as those always yielding saltish *gur*.

These findings are generally at variance with those of Krishnamurthy Rao [1919] who concluded that thick juicy canes do not absorb as much chlorine as thin hardy varieties. Norris, Viswanath and Nayar [1924] do not refer to saltishness in *gur* at all, but state that the keeping quality is impaired by deliquescent compounds of chlorine.

#### *Saltishness in gur*

*Gur* samples made from the 18 varieties under trial at the Himayatsagar Farm with four replications of each variety were analyzed to determine as to what constituent in the ash of *gur*, is responsible for saltishness. Results of these analyses are given in Table VI. It will be seen from the results that the constituents of the ash of *gur* vary for the same variety in the different replications, and that *gur* of the same variety in some plots is saltish while in others it is sweet. This is probably due to the uneven distribution of salts in the different plots.

Total alkalinity and sulphates do not seem to exert any specific effect on the taste of *gur*. Samples containing over 0.50 per cent of chloride content are generally saltish and almost all samples containing less than 0.50 per cent chlorine (0.82 per cent NaCl) are sweet even though the total alkalinity and sulphates are quite high. Taking the average of four years, of the 72 samples only 42 are saltish and 30 sweet. Amongst them, there were only four samples with less than 0.50 per cent chlorine that were saltish and only four samples with more than 0.50 per cent chloride that were sweet. Thus the correlation between the chlorine content of *gur* and taste seems to be quite convincing. Generally speaking, if *gur* samples contain over 0.50 per cent of chlorine they would be saltish, while those containing less would be sweet.

The sulphate content of *gur* varied from 0.17 to 1.05 per cent. These are two extreme samples out of a total of 288 during the four years. In 1939-40, a *gur* sample made from Co. 434, contained 1.05 per cent sulphate and only 0.43 per cent chlorine. It was not saltish, although the taste was unpleasant.

Samples high in total alkalinity usually have a biting taste but not saltish if the chlorine content is less than 0.5 per cent.

## OTHER OBSERVATIONS

Vaticol, a patented vegetable carbon, was used in the manufacture of *gur* in 1939-40 to get a light-coloured product in the first and second replications of Co. 419, 421, 423, 520, 523, 524, 530 and 532 and in the first and third replications of the remaining ten varieties. It did not have any effect, either on alkalinity in the ash of *gur* or on taste of *gur*.

Incidentally, there does not seem to be any definite relation between saltishness and texture of *gur* samples.

## RECOMMENDATION

It is now evident why complaints of saltishness in *gur* of Coimbatore sugarcane varieties are received only from new sugarcane areas. In the old areas, the salts present in the soil, especially chlorides which are responsible for saltishness, were either removed by the previous sugarcane crops or leached out; hence sweet *gur* results. In the new areas on the other hand, the sugarcane crop itself absorbs the salts from the soil; and if chlorides are present, saltish *gur* is produced. This does not present a problem to cane growers in the factory areas, as all the cane is sold to the factory. In the non-factory areas, however, where sugarcane is being newly introduced, this fact must be taken into account. As a safeguard, therefore, one may grow a variety of sugarcane like Co. 419 which always yields sweet *gur*, or grow at least two crops of paddy prior to sugarcane cultivation in order to leach out the salts present in the soil and to minimise the chances of producing saltish *gur* which would naturally command a lower price in the market.

Some of the varieties like Co. 290 and 301 which seem to absorb large amounts of salts in the soil, may be cultivated in saline soils along with systematic leaching. Co. 290 is found to be a very hardy cane, able to thrive in waterlogged conditions also. As such, it can be recommended for waterlogged soils as well as reclamation of saline soils.

## SUMMARY

Coimbatore sugarcane varieties when cultivated in new areas, yield *gur*, high in alkalinity in ash directly depending upon the water soluble salts in the soils and irrigation waters which are absorbed by the plants.

The alkalinity in ash is lower in *gur* made from ratoon sugarcanes than in *gur* from plant (new crop) canes. Also a great number of *gur* samples from ratoon canes is sweet or less saltish than from new crop. This indicates that on continued cane cultivation, the *gur* produced will tend to be less alkaline and less saltish to taste. In other words, it tends to become sweet.

Sweet *gur* was always yielded by Coimbatore sugarcane variety 419, and almost always by 434. On the other hand, Co. 290, 301 and 244 always gave saltish *gur*. This may be a varietal characteristic indicating selective absorption of the salts present in the soil.

There was no correlation between the taste of *gur* and total alkalinity in its ash. Some *gur* samples with high alkalinity had a sweet taste while others with very low alkalinity had saltish taste.

Saltishness in *gur* is due to the presence of chlorides in it. If the chlorine content is more than 0.50 per cent the *gur* tastes saltish. The sulphate content has no such effect.

For new irrigated areas, it is suggested that a variety of sugarcane like Co. 419 which always yields sweet *gur* may be grown. In the alternative, prior to the introduction of Coimbatore sugarcane varieties, ryots may be advised to cultivate paddy for at least two seasons before planting cane, so that the chances of obtaining saltish *gur* become minimized.

For reclaiming saline areas Co. 290, a very hardy variety, may be recommended along with systematic leaching, as this variety not only absorbs large amounts of salts but also withstands water-logging.

#### REFERENCES

- Bhushanam, K. (1945). The effect of fertilizers on sugarcane. *Mad. Agr. Jour.* **33**
- Holmes, R. L. (1938). *Proc. Int. Soc. Sug. Tech* : 6th Congress, Baton Rouge, Louisiana, **314**
- Krishnamurthy Rao, K. (1919). The Effect of Salinity on the growth and composition of sugarcane varieties. *Agri. Jour. Ind.* **14**, **476**
- Lander, P. E. and Ramji Narain (1939). Sugarcane in the Punjab. *Ind. Jour. Agr. Sc.*, **9**, **381**
- McKaig and Fort (1938). *Proc. Int. Soc. Sug. Tech* : 6th Congress, Baton Rouge, Louisiana, **319**
- Norris, Viswanath and Govindanayar (1922). Improvement in Cocanutt Jaggery Industry on the west coast. *Agr. Jour. Ind.*, **17**, **353**
- Govinda Nayar, (1924). Improvement in Cocanutt Jaggery Industry on the West Coast. Part II. *Agri. Jour. Ind.*, **19**, **485**
- Sanyal, P. B. (1928). A preliminary note on the effect of manurial constituents on the quality of sugarcane juice and *gur*. *Agri. Jour. Ind.*, **21**, **277**
- Swadi, T. S. (1919). A preliminary note on some new factors affecting the hardness of *gur* or crude sugar. *Agr. Jour. Ind.*, **14**, **45**
- Varahalu, T. (1935). Physico-Chemical studies on sugarcane jaggery. *Mad. Agri. Jour.*, **23**, **389**
- Varahalu, T. (1936). Studies in Sugarcane. *Mad. Agri. Jour.*, **24**, **394**
- Willcox, O. W. (1946). The Agrobiologic test for normality in fertilizer experiments and variety comparisons I. *Jour. Am. Soc. Agr.*, **38**, **3**, **218**
- Willcox, O. W. (1946). The Agrobiologic test for normality in fertilizer experiments and variety comparisons II. *Jour. Am. Soc. Agr.*, **38**, **4**, **308**

TABLE I  
Analysis of 'Gur' samples from different localities of the State and Govt. farms, 1934

Series Number	Variety	Locality	Description	Moisture per cent	Sucrose per cent	Reducing sugars per cent	Ash per cent	Alkalinity in ash per 100 gms. sample	Remarks (clarifiers, manures, etc.)
1	Co. 213	Himayat sagar farm	Reddish brown, soft, saltish	5.18	86.67	5.26	3.16	13.50 cc. N. acid	Sajikhar, and improved as clarifier
2	Co. 213	do.	do.	6.06	84.84	2.86	3.89	11.9 "	do.
3	Co. 213	do.	Reddish brown, hard	4.28	83.44	5.71	3.10	8.1 "	do.
4	Co. 213	do.	Yellowish B, hard	3.68	86.60	3.57	2.47	7.4 "	do.
5	Co. 213	Saidapur	Brown, sweet, hard	2.88	82.04	7.81	3.26	5.4 "	Improved as clarifier
6	Co. 213	Nanded	Soft, dark B	3.64	78.34	8.00	3.76	13.2 "	Improved as clarifier
7	Co. 213	Mahboobnagar farm	Black with yellow tinge, sticky	5.95	70.93	8.65	4.81	8.6 "	Sajikhar, and improved as clarifier
8	Co. 213	Rudrur farm	Golden yellow, sweet and hard	1.93	78.73	10.00	2.44	7.00 "	do.
9	Co. 213	do.	Reddish B, hard, saltish	1.90	85.63	5.86	4.26	11.5 "	Castor cake 1200 lbs. (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
10	Co. 213	do.	Golden yellow, hard, saltish	1.92	87.20	5.88	5.30	9.5 "	Castor cake 1600 lbs. (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
11	Co. 213	do.	Reddish B, sweet, hard	2.60	79.43	12.41	2.87	8.3 "	Castor cake 2000 lbs. (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
12	Co. 213	do.	Dirty B, sweet and hard	2.70	80.64	9.53	4.33	7.4 "	Castor cake 2400 lbs. (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
13	Co. 213 regar soil	do.	Pale reddish B, sweet, hard	2.50	80.55	9.62	1.02	5.1 "	Planted on 15th January 1933
14	Co. 213 regar soil	do.	do.	1.30	80.92	9.90	1.33	4.7 "	Planted on 15th February 1933
15	Co. 213 regar soil	do.	Golden yellow, sweet, hard	1.40	81.99	9.71	2.11	6.00 "	Planted on 15th March 1933

16	Co. 213 regar soil	do.	Golden yellow, sweet, not so hard	3.10	70.25	9.45	2.41	5.22	Planted on 15th April 1933
17	Co. 213 regar soil	do.	Reddish B, sweet, hard	2.70	80.40	13.04	2.04	spotted	Planted on 15th November 1932
18	Co. 213 regar soil	do.	Pale yellow, sweet, not so hard	3.20	76.75	16.88	2.05	2.5	Planted on 15th December 1932
19	Co. 213 chalka	do.	Golden yellow, sweet, hard	1.70	73.80	10.84	2.67	4.4	Planted on 15th November 1932
20	Co. 213 chalka	do.	do.	1.60	77.71	11.07	1.88	3.1	Planted on 15th December 1932
21	Co. 213 chalka	do.	do.	1.60	80.86	11.97	2.25	4.7	Planted on 15th January 1933
22	Co. 213 chalka	do.	do.	1.26	72.39	10.95	2.23	6.1	Planted on 15th February 1933
23	Co. 213 chalka	do.	do.	1.20	74.55	11.44	1.53	3.00	Planted on 15th March 1933
24	Co. 213 chalka	do.	Reddish B, sweet, hard	1.60	73.03	8.96	2.55	6.2	Planted on 15th April 1933
25	Co. 213 chalka	Parbhani	Dark B, burnt flavour, soft	4.90	79.28	12.56	4.35	3.2	Sajjekar, blevis juice as clarifier
26	Co. 223	Himayat sagar farm	Reddish brown, soft, saltish	6.85	82.86	4.44	3.17	13.0	do.
27	Co. 223	do.	Slightly saltish	7.17	82.00	3.84	3.16	9.8	do.
28	Co. 223	do.	do.	3.84	81.11	3.33	2.58	9.7	do.
29	Co. 223	do.	Reddish brown, soft, sweet	4.09	87.59	4.34	1.64	8.7	do.
30	Co. 223	Rudrur farm	Yellowish B, sweet, hard	3.00	72.20	15.37	3.32	8.0	do.
31	Co. 223	Parbhani farm	Dark B, burnt flavour, soft	3.60	80.35	11.44	4.22	3.3	do.
32	Co. 281	Himayat sagar farm	Reddish brown, soft, slightly saltish	7.32	79.79	6.70	3.56	9.6	do.
33	Co. 281	do.	do.	4.67	83.37	5.46	2.30	8.4	do.
34	Co. 281	do.	Dark brown, hard, slightly saltish	3.63	74.39	2.70	2.75	7.8	do.
35	Co. 281	do.	Yellowish brown, hard, slightly saltish	2.10	85.25	4.40	2.13	7.7	do.
36	Co. 281	Rudrur farm	Dark brown hard, sweet	2.10	80.55	9.02	1.73	5.5	do.
37	Co. 281	Parbhani farm	Reddish brown, soft, B flavour	4.00	77.10	7.36	4.84	3.8	do.

TABLE I—contd.

*Analysis of 'Gur' samples from different localities of the State and Govt. farms, 1931—con d.*

Serial number	Variety	Locality	Description	Moisture per cent	Sucrose per cent	Reducing sugars per cent	Ash per cent	Alkalinity in ash per 100 gms. sample	Remarks (clarifiers, manures, etc.)
38	Co. 290	Himayat sagar farm	Reddish brown, soft, sweet	5.83	80.26	5.88	4.06	1.6 N. Ucid	Sajjsekhar, blend juice as clarifier
39	Co. 290	do.	do.	6.67	83.88	6.53	3.16	8.1 "	do.
40	Co. 290	do.	do.	6.73	84.49	6.88	3.47	8.4 "	do.
41	Co. 290	do.	Yellowish brown, sweet, hard	3.34	74.48	6.48	2.81	8.6 "	do.
42	Co. 290	Rudrur farm	Dirty brown, hard, sweet	3.50	76.40	15.60	2.95	8.3 "	do.
43	Co. 290	Parbhani farm	Dark brown, saltish, sour, soft	4.20	73.01	10.30	5.55	6.1 "	do.
44	Poj. 2878	Himayat sagar farm	Yellowish brown, soft, sweet	4.75	86.24	5.71	2.35	7.5 "	do.
45	Poj. 2878	do.	do.	6.50	86.27	2.40	1.64	5.4 "	do.
46	Poj. 2878	do.	do.	5.72	78.93	2.86	2.55	9.5 "	do.
47	Poj. 2878	do.	Dark brown, hard, sweet	3.35	81.25	7.70	2.53	6.9 "	do.
48	Poj. 2878	Rudrur farm	Pale brown, sweet, hard	2.50	75.72	14.71	2.07	4.8 "	do.
49	Poj. 2878	Parbhani farm	Reddish brown, soft, B flavour, contains much foreign matter	5.8	77.91	9.36	3.01	3.0 "	do.
50	Poj. 2714	Himayat sagar farm	Golden yellow, sweet, soft	6.70	86.43	3.25	2.20	5.8 "	do.
51	Poj. 2714	do.	Yellowish B., sweet, slightly soft	4.77	85.52	4.16	1.86	8.9 "	do.
52	Poj. 2714	Rudrur farm	Golden yellow, sweet, hard	2.00	85.54	7.63	2.28	5.7 "	do.
53	Poj. 2723	do.	Reddish brown, sweet, very hard	1.30	86.46	8.37	1.60	4.5 "	do.
54	H. M. 544 (striped)	Himayat sagar farm	Reddish brown, sweet, soft	7.00	81.01	8.43	1.94	5.5 "	do.
55	H. M. 544 (striped)	do.	Yellowish brown, little soft, sweet	4.32	88.01	3.38	1.38	6.4 "	do.
56	H. M. 544 (striped)	Rudrur farm	Pale brown, sweet, hard	2.50	75.29	12.12	1.54	2.4 "	do.



TABLE II

*Comparison of alkalinity in 'gur' made from Coimbatore sugarcane varieties cultivated at Rudrur Govt. Farm, Nizamabad District, and Himayatsagar Main Farm, Hyderabad-Deccan*

Expressed as normal c. c. acid required to neutralize alkalinity in ash of 100 gm. 'gur'

Serial number.	Variety	Himayatsagar			Rudrur		
		1935-36	1936-37	1937-38	1935-36	1936-37	1937-38
1	Co. 205	..	6.80	4.8	..	..	..
2	Co. 213	4.8 to 7.2	3.80	5.8	1.7 to 3.2	..	2.4
3	Co. 219	..	6.40	..	..	..	..
4	Co. 223	2.6 to 4.9	6.60	4.0	1.7	1.1	1.0
5	Co. 244	..	4.80	4.2	..	..	..
6	Co. 270	..	7.00	4.4	..	..	..
7	Co. 281	4.4 to 6.2	7.20	3.8	2.3	1.4	1.2
8	Co. 285	..	8.80	5.6	..	..	..
9	Co. 290	4.7 to 7.7	6.60	6.2	3.45	2.7	1.6
10	Co. 299	..	7.00	..	..	..	..
11	Co. 300	3.2 to 6.4	6.00	8.2	..	1.8	1.3
12	Co. 301	..	4.40	5.2	..	1.4	1.4
13	Co. 313	5.8 to 7.3	7.80	5.0	..	2.2	1.4
14	Co. 326	..	9.40	..	..	..	..
15	Co. 331	4.9 to 7.8	7.60	3.4	..	1.6	1.2
16	HM. 320	3.2 to 6.4	4.5	2.8	..	0.4	1.2
17	HM. 544	2.8 to 5.1	4.4	..	..	0.4	1.0
18	HM. 544 str.	..	5.4	..	1.9	1.6	1.2
19	HM. 608	..	5.8	4.0	..	..	..
20	HM. 613	..	7.0	5.8	..	..	..

TABLE—contd.

Serial Number.	Variety	Himayatsagar			Rudrur		
		1935-36	1936-37	1937-38	1935-36	1936-37	1937-38
21	HM 617	..	3.8	6.2	..	..	..
22	HM 627	..	6.0	4.2	..	..	..
23	Poj 2714	3.4 to 5.5	5.0	2.8	2.85	1.4	1.0
24	Poj 2725	..	3.3	4.0	..	0.6	1.6
25	Poj 2878	3.2 to 4.9	5.6	3.0	2.5	0.6	1.2
26	Poj 2883	..	7.4	..	..	0.7-3.0	0.8
27	D 109	..	5.4	..	..	1.1	1.6
28	Fiji B	..	5.4	..	..	1.2	0.8
29	Ek 28	2.8 to 3.4	6.6	3.2	3.25	0.6	1.6

TABLE III

Water soluble salts in soils and irrigation waters from Rudrur Government Farm, Nizamabad District, and Himayatsagar Main Farm, Hyderabad

Soluble salts in Rudrur chelka soils. (Red sandy loams)

Serial Number.	No. of plot	Parts per 100,000				SO <sub>4</sub>
		Total salts	CO <sub>3</sub>	HCO <sub>3</sub>	Cl	
1	A5c	67	..	42.7	3.5	..
2	C11	62	..	30.5	7.0	..
3	A1a	136	..	73.2	17.5	..
4	A1c	80	..	48.8	7.0	..
5	A1b	84	..	48.8	10.5	..
6	A5b	124	..	73.2	7.0	..
7	C10	78	..	48.8	3.5	..
8	A2bc	126	..	73.2	3.5	..
9	A2a	68	..	30.5	7.0	..
10	A2bc	126	..	73.2	10.8	..

TABLE—*contd.*

Soluble salts in Himayatsagar cane soils. (Black clay loams)

Serial Number.	Parts per 100,000					SO <sub>4</sub>
	No. of plot	Total salts	CO <sub>2</sub>	HCO <sub>2</sub>	Cl	
1	A	110	..	73.2	3.5	..
2	B	120	..	73.2	7.0	..
3	C	114	..	67.1	5.25	..
4	D	68	..	30.5	5.25	..
5	E	80	..	42.7	7.0	..
6	F	130	..	79.3	5.25	..

## Salts in waters

Serial Number	Source of irrigation	Location of sampling	Parts per 100,000				
			Total salts	CO <sub>2</sub>	HCO <sub>2</sub>	Cl	SO <sub>4</sub>
1	Nizamsagar canal	Rudrur farm	14.2	3.2	5.4	1.05	..
2	Nizamsagar canal	Rudrur, outside farm	13.1	..	8.2	1.05	..
3	Nizamsagar canal	Near Varni Nizamabad	11.8	2.7	5.4	0.70	..
4	Himayatsagar canal	Himayatsagar farm	21.1	1.8	12.2	1.05	..

TABLE IV

*Alkalinity in 'gur' made from plant and ratoon sugarcanes of Coimbatore varieties cultivated at Himayatsagar Main Farm*

Serial Number.	Variety	Alkalinity in ash from 100 gms. <i>gur</i> expressed as c.c.N. acid and taste					
		1933-34 new crop	1934-35 Ratoon	1934-35 new crop	1935-36 Ratoon	1935-36 new crop	1936-37 Ratoon
1	Co. 213 a	13.5 slt	5.0 sw	7.4 ssl	5.5 sw	4.8 sw	4.0 sw
2	Co. 213 b	11.9 slt	5.6 sw	8.7 ssl	4.9 ssl	6.8 sw	4.6 sw
3	Co. 213 c	8.1 slt	4.4 sw	5.6 sw	4.6 sw	7.2 ssl	5.0 sw
4	Co. 213 d	7.4 slt	5.6 sw	7.6 sw	3.2 sw	6.4 sw	5.9 slt
5	Co. 213 e	..	..	..	..	6.0 ssl	4.6 ssl
6	Co. 213 f	..	..	..	..	6.1 sw	3.9 ssl
7	Co. 223 a	13.0 slt	3.5 sw	9.6 sw	4.0 ssl	4.7 slt	3.4 sw
8	Co. 223 b	9.8 slt	5.1 sw	9.2 sw	3.4 slt	2.6 slt	3.0 sw
9	Co. 223 c	9.7 slt	3.1 sw	7.3 sw	4.3 ssl	4.8 sw	4.2 sw
10	Co. 223 d	8.7 sw	4.3 sw	7.3 ssl	4.4 sw	4.3 ssl	2.6 sw
11	Co. 223 e	..	..	..	..	4.6 ssl	6.2 sw
12	Co. 223 f	..	..	..	..	4.9 ssl	3.8 ssl
13	Co. 281 a	9.6 slt	4.8 sw	6.4 sw	3.2 slt	15.1 slt	3.8 sw
14	Co. 281 b	8.4 slt	4.4 sw	5.6 sw	3.6 slt	6.2 slt	3.4 sw
15	Co. 281 c	7.8 slt	3.6 sw	7.2 sw	3.1 sw	4.3 slt	3.2 ssl
16	Co. 281 d	7.7 ssl	3.4 slt	6.2 sw	3.9 slt	4.0 sw	4.6 sw
17	Co. 281 e	..	..	..	..	4.5 slt	3.0 sw
18	Co. 281 f	..	..	..	..	4.7 slt	2.1 ssl
19	Co. 290 a	1.6 sw	2.7 sw	7.2 ssl	2.8 slt	5.1 ssl	3.8 sw
20	Co. 290 b	8.1 sw	4.7 slt	4.8 sw	5.3 slt	6.6 ssl	4.8 ssl
21	Co. 290 c	8.4 sw	3.5 slt	7.8 ssl	7.0 slt	7.7 ssl	5.8 ssl
22	Co. 290 d	8.6 sw	2.9 slt	4.8 ssl	3.4 slt	7.4 slt	5.3 slt
23	Co. 290 e	..	..	..	..	4.7 slt	5.8 slt
24	Co. 290 f	..	..	..	..	7.4 slt	3.4 slt

ssl=slightly saltish

slt=saltish

sw=sweet

TABLE V

*Alkalinity and taste of 'gur' samples of 20 leading varieties under trial at the Main Farm  
Himayatsagar, Hyderabad, for three years*

Serial Number.	Variety	Alkalinity			Taste		
		c.c.N. acid required for ash in 100 grams 'gur'			Line tests : 6 lines for each variety		
		1936-37	1937-38	1938-39	1936-37	1937-38	1938-39
1	Co. 419	8.7	3.8	3.6	S.St.	S.St.	Sw.
2	Co. 423	5.6	4.4	4.9	S.St.	S.St.	Sw.
3	Co. 426	5.6	4.4	3.9	S.St.	St.	S.St.
4	Co. 434	6.0	6.0	4.4	Sw.	S.St.	Sw.
5	Co. 524	..	..	4.3	..	..	S.St.
6	Co. 523	..	..	4.4	..	..	Sw.
7	Co. 421	5.4	5.8	5.4	Sw.	Sw.	Sw.
8	Co. 301	4.4	5.2	4.1	St.	Sw.	S.St.
9	Co. 520	..	..	4.6	..	..	S.St.
10	Co. 290	6.6	6.2	4.5	S.St.	St.	St.
11	Co. 511	5.6	4.6	4.6	St.	Sw.	Sw.
12	Co. 413	5.1	3.8	3.9	St.	Sw.	S.St.
13	Co. 530	..	..	6.6	..	..	Sw.
14	Co. 408	3.5	3.2	6.1	Sw.	S.St.	Sw.
15	Co. 244	4.8	4.2	4.9	Sw.	S.St.	S.St.
16	Co. 513	7.8	5.4	6.9	St.	S.St.	St.
17	Co. 331	7.6	3.4	5.8	St.	Sw.	S.St.
18	Co. 429	7.8	4.8	6.5	Sw.	Sw.	Sw.
19	Co. 509	6.6	5.4	6.2	Sw.	Sw.	Sw.
20	Co. 313	7.8	5.0	4.9	Sw.	S.St.	Sw.

St. = Saltish

S.St. = Slightly saltish

Sw. = Sweet

TABLE VI

Statement showing the analysis of 'gur' samples together with their taste for superior varieties under trial at the Government Agricultural Experiment Station, Hidayatnagar, Hyderabad-Dc. for the year 1939-43

Serial Number.	Variety	Taste				Per cent chlorine (Cl)				Per cent sulphate (SO <sub>4</sub> )				Alkalinity (c.c. of normal required for 100 gm. gur)			
		1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43	1939-40	1940-41	1941-42	1942-43
1	Co. 214	Sweet	Saltish	Saltish	Sweet	0.34	0.50	0.60	0.58	0.54	0.41	0.61	0.42	5.4	9.8	8.2	11.3
2	Co. 290	Saltish	Saltish	Highly Saltish	Saltish	0.60	0.82	0.96	0.73	0.59	0.46	0.60	0.40	4.9	7.2	6.4	9.3
3	Co. 301	Saltish	Saltish	Saltish	Saltish	0.57	0.59	0.53	0.72	0.75	0.54	0.76	0.58	4.6	12.5	8.2	11.5
4	Co. 313	Saltish	Saltish	Saltish	Saltish	0.64	0.57	0.66	0.60	0.56	0.54	0.64	0.40	6.0	11.6	9.7	13.0
5	Co. 361	Saltish	Saltish	Highly Saltish	Saltish	0.56	0.57	0.70	0.68	0.75	0.40	0.73	0.61	3.6	13.9	4.4	8.8
6	Co. 405	Sweet	Sweet	Saltish	Saltish	0.39	0.37	0.48	0.42	0.64	0.40	0.72	0.49	2.7	6.5	4.6	5.2
7	Co. 413	Saltish	Saltish	Saltish	Sweet	0.56	0.60	0.50	0.43	0.51	0.57	0.52	0.41	6.7	10.8	15.4	8.5
8	Co. 419	Sweet	Sweet	Sweet	Sweet	0.35	0.33	0.41	0.33	0.45	0.50	0.51	0.42	3.0	3.6	5.0	9.4
9	Co. 421	Sweet	Saltish	Sweet	Sweet	0.47	0.57	0.10	0.36	0.50	0.58	0.29	0.54	4.5	12.1	5.4	10.0
10	Co. 423	Saltish	Indif-nite	Sweet	Sweet	0.60	0.52	0.20	0.50	0.86	0.33	0.23	0.51	4.5	9.5	5.1	10.7
11	Co. 426	Saltish	Saltish	Saltish	Sweet	0.45	0.58	0.53	0.47	0.53	0.43	0.61	0.50	4.4	10.6	4.6	7.6
12	Co. 434	Sweet	Indif-nite	Sweet	Sweet	0.45	0.45	0.46	0.53	0.86	0.43	0.46	0.39	5.0	8.4	5.5	9.8
13	Co. 513	Saltish	Saltish	Highly Saltish	Saltish	0.65	0.67	0.80	0.81	0.67	0.61	0.70	0.49	4.1	10.7	7.0	12.0
14	Co. 520	Sweet	Saltish	Indif-nite	Sweet	0.43	0.47	0.46	0.40	0.53	0.52	0.59	0.57	4.1	9.8	6.1	11.5
15	Co. 525	Sweet	Saltish	Saltish	Sweet	0.38	0.58	0.49	0.51	0.59	0.62	0.81	0.61	5.2	10.0	5.7	10.2
16	Co. 524	Indif-nite	Sweet	Saltish	Saltish	0.50	0.46	0.53	0.61	0.75	0.50	0.70	0.57	5.7	12.4	11.8	19.1
17	Co. 530	Indif-nite	Sweet	Sweet	Sweet	0.50	0.37	0.34	0.43	0.55	0.56	0.69	0.48	5.8	9.9	8.4	15.1
18	Co. 532	Saltish	Indif-nite	Saltish	Indif-nite	0.63	0.46	0.53	0.55	0.61	0.58	0.44	0.33	3.1	5.3	6.8	11.4

N.B.—The results are averages of four replications



## REVIEWS

### CHEMICAL COMPOSITION OF PLANTS AS AN INDEX OF THEIR NUTRITIONAL STATUS

By D. W. GOODALL AND F. G. GREGORY

*(Published by the Imperial Bureau of Horticulture and Plantation Crops, August, 1947, pp. 167 and bibl. 936, Rs. 9)*

THIS is a monograph full of closely packed information, in which the authors have attempted to estimated the value of plant-analysis methods with the critical acumen, necessary for successful research. The results of previous workers have also been carefully collected and assembled in a manner of great usefulness.

It is often claimed that the composition of the plant reflects its nutritional status, the adequacy of nutritional supplies and the probability of its response to increased supplies. The examination of these claims forms the principal topic of this highly useful monograph, the ultimate object of which, is to obtain a solution of the central problem, the determination of fertilizer requirements. The book starts with an introductory review of the different methods of assessing fertilizer requirements and a detailed consideration of the various methods, which have been proposed and attempted, finally coming to the use of plant-analysis and comparison of the value with those of other techniques.

There are in all 15 Tables, of which, Table I extends over 16 pages, giving the published data of the content of nutrients in plants, showing symptoms of nutritional disorder. These have been reproduced in summary forms and contrasted with data for otherwise comparable forms not showing the symptoms. Similarly, Table II gives the limiting value, below which, deficiency symptom and above which, toxicity symptoms may occur. Another Table (Table XII), gives the standard values of 'nutrients content' proposed in the literature. These are as much interesting as useful.

The 'author-index' covers over 800 entries. The bibliography gives the titles and references of the papers and publications, whereas, the 'subject-index' and 'author-index' are put up separately. The arrangement thus facilitates easy reference.

The correct criterion for assessing the value of any method for the fertilizer requirements depends on the accuracy with which the response to fertilizer additions can be forecast. The pre-requisite for it is, a series of comprehensive experiments in which the samples of plant material have to be taken for analysis before the

fertilizers, whose effects are to be predicted, are applied. The chemical composition of the plant, if estimated at the right stage, offers a great saving of labour, besides the fact, that the results can be obtained with very little delay. This has prompted the authors to give a general survey of the use of plant analysis for diagnostic purpose showing the main lines of development during the last two decades. Here 'tissue tests' methods deserve special mention on account of the rapidity with which it enables determination of the deficiency. The theory behind this method is based on the natural probability that the nutrients present in the conducting tissues consist largely of unassimilated materials and hence their concentration will represent their current rate of intake. The senior author, in particular, has done considerable work relating to the diagnosis of mineral deficiency. The 'tissue tests' method holds out great promise and needs to be tried on a still wider scale.

The book is an epitome of great care, erudition and labour, and will be of great service to all research workers.

Incidentally, it reveals how little work on these important aspects have been conducted in India. (I.C.)

## FARM SCIENCE AND CROP PRODUCTION IN INDIA

BY C. P. DUTT AND B. M. PUGH

(Published by Kitabistan, Allahabad, 1947, pp. 240, Rs. 12)

**T**HIS is the second edition of the book but the original name 'Crop Production in India' has been somewhat modified.

As in the first edition, the book is divided into two parts but here also the title has been changed. Part I has been named 'Farm Science' in place of 'General Principles of Crop Production,' and Part II 'Crop Production in India' in place of 'Field Crops'. Both parts have been separately paged. The more welcome change in the book is its size which has now become handier, smaller and lighter. The portions dealing with statistical method and laying out of field experiments have been deleted. The older data on crop and other statistics have been replaced by newer ones 1941 but it would have been more helpful if the more recent data on the basis of Indian Union and Pakistan had been included. Such data are available. Another omission here is that whereas the newer statistics have been taken largely from 1941 data, the corresponding correction has not been made in the bibliography under the different chapters where generally the reference is to the older publication as given in the first edition. In Table V, page 33 some of the botanical names are older ones. They differ from those given in the *Kew Bulletin* by Sampson. They

should be suitably corrected. In this Table 'common names' have been given. It would have helped the readers of the different provinces if the important vernacular names had been included either here or separately in the chapter dealing with individual crops.

In part II, page 14, the total estimated yield of wheat has been given at 12 million tons (324 million md.). On the other hand in Table III, page 11 the production of wheat has been shown at 257.275 million md. Evidently both these data have been taken from different sources or possibly there is some error. Similar checking is also needed in the case of other data and as they are of very great importance the author's attention is invited to them.

Under maize there is no mention about the recent development on hybrid maize. Under minor oilseeds mustard crop has been included. I do not know on what ground it has been considered as minor oilseed as both mustard and mustard oil are of major importance all over Northern India.

The authors have produced a useful book but it would have been much better if they had confined their attention to the main aspect of crop production instead of attempting rather too many things.

In citing references the authors should do it on the basis of latest books and periodicals. Here too there is much room for improvement. (I. C.)

# CENTRAL BOARD OF IRRIGATION NOTIFICATION

## THE CENTRAL BOARD OF IRRIGATION MEDAL RULES

**T**HE C.B.I. Medal has been instituted to encourage research relating to and the technique and development of the water resources of India and all devices and matters connected therewith.

The Medal will be awarded at the annual meeting of the Board to a person (or persons) whose contribution to research (basic or applied) technique, theory or practice relating to the development of the water resources of India is adjudged by the Executive Committee of the Board to be an outstanding original contribution of the preceding year.

The year for purposes of award of the medal will be the calendar year.

The contribution may be in the form of a paper presented to the annual meeting of the Research Committee of the Central Board of Irrigation or to any other engineering institution in India or may be an article published for the first time in the C.B.I. Journal or any other technical journal published in India.

Applications for the award should be addressed to the Secretary, Central Board of Irrigation, Kennedy House, Simla 4, so as to *reach him before the 1st March\**, each year and unless the paper or article has been presented to the C.B.I. Research Committee or published in the C.B.I. Journal, the application should be accompanied with five copies of the article or paper.

The merit of the award shall be adjudged by and at a meeting of the Executive Committee of the C.B.I., which is usually held at the time of the annual Research Committee meeting. The decision of the Executive Committee will be final and binding on the applicants. No correspondence will be entered into with regard to the decision of the Executive Committee and this is a necessary condition of entries in the competition.

In case no contribution is considered to be of the requisite high standard from among those which enter the competition, the Executive Committee may decide not to make any award in a particular year.

---

\*For paper and article published during the year 1948, the date has been extended to 30th April, 1949.

## COMMONWEALTH AGRICULTURAL BUREAUX

The organization formed by the Governments of the British Commonwealth provides up-to-date information in the form of abstracting and reviewing journals, technical communications and bibliographies on all aspects of science and practice as applied to agriculture, horticulture and forestry.

### JOURNALS

The following list comprises journals and other periodical publications. Subscription rates are quoted after each; in certain cases (journal marked with an asterisk) a 20 per cent deduction is made for subscribers in the British Commonwealth who send their subscriptions direct and not through a bookseller.

Bulletin of Entomological Research	40s.	*Plant Breeding Abstracts	35s.
Review of Applied Entomology (Series A)	40s.	*Herbage Abstracts	35s.
Review of Applied Entomology (Series B)	20s.	*Field Crop Abstracts	35s.
Review of Applied Mycology	40s.	*Horticultural Abstracts	35s.
*Soils and Fertilizers	35s.	*Animal Breeding Abstracts	35s.
Veterinary Bulletin	40s.	Helminthological Abstracts	35s.
Index Veterinarius	100s.	*Dairy Science Abstracts	35s.
Nutrition Abstracts and Reviews	60s.	*Forestry Abstracts	45s.
		Forest Products and Utilization	15s.

All enquiries regarding these publications should go to:—

**COMMONWEALTH AGRICULTURAL BUREAUX,  
Central Sales Branch, Penglais, Aberystwyth, Great Britain.**

## COMMONWEALTH AGRICULTURAL BUREAUX

**Journals.**—The following list comprises journals and other periodical publications. Subscription rates are quoted after each.

Bulletin of Entomological Research	40s.	Field Crop Abstracts	35s.
Review of Applied Entomology (Sr. A)	40s.	Herbage Abstracts	35s.
Review of Applied Entomology (Sr. B)	20s.	Horticultural Abstracts	35s.
Review of Applied Mycology	40s.	Animal Breeding Abstracts	35s.
Soils and Fertilizers	35s.	Helminthological Abstracts	35s.
Veterinary Bulletin	40s.	Dairy Science Abstracts	35s.
Index Veterinarius	100s.	Forestry Abstracts	45s.
Nutrition Abstracts and Reviews	60s.	Forest Products and Utilization	15s.
Plant Breeding Abstracts	35s.		

### Occasional Publications

	Price.
Phenothiazine 1942-46: a review and bibliography	4s.
The use and misuse of shrubs and trees as fodder	9s.
The use of aerial survey in forestry and agriculture—By J. W. B. Sisam	7s. 6d.
The technique of breeding for drought resistance	2s. 6d.
The grasslands of Latin America—By Miss G. M. Roseveare	20s.
Five hundred varieties of herbage and fodder plants	15s.
Seed production of European vegetables in the tropics—By A. G. G. Hill	2s.
Spectrographic analysis of soils, plants and relating materials	12s. 6d.
List of research workers: agriculture and forestry in the British Commonwealth (1947)	7s. 6d.
The effect of rainfall on plant disease distribution in the Anglo-Egyptian Sudan—By A. S. Boughey	3s.
Species of Alternaria on Brassicæ—By S. P. Wiltshire	3s.
The causes of variation in the incidence of Blackarm Disease of cotton in the Sudan Gezira—By A. S. Boughey	2s. 3d.
The causes of variation in the incidence of cotton leaf curl in the Sudan Gezira—By A. S. Boughey	2s. 3d.

All correspondence, subscriptions and requests for specimen copies of journals to:—

**COMMONWEALTH AGRICULTURAL BUREAUX,  
Central Sales Branch, Penglais, Aberystwyth, Wales.**

## Publication Committee

- SARDAR DATAR SINGH, F.R.S.A.,** *Vice Chairman, Indian Council of Agricultural Research*
- D. R. SETHI, I.A.S.,** *Agricultural Development Commissioner with the Government of India*
- R. L. SETHI, I.A.S.,** *Agricultural Commissioner with the Government of India*
- P. N. NANDA, M.R.C.V.S., D.V.S.M.,** *Animal Husbandry Commissioner with the Government of India*
- J. N. MUKHERJEE, D.Sc., F.N.I., F.R.A.S.B., F.C.S.,** *Director, Indian Agricultural Research Institute, New Delhi*
- S. DUTTA, D.Sc., M.R.C.V.S., D.T.V.M., F.R.S., (Edin.), F.N.I.,** *Director, Indian Veterinary Research Institute, Mukteswar*
- K. C. SEN, D.Sc.,** *Director, Indian Dairy Research Institute, Bangalore*
- S. SWALLEHEY, Ph.D.,** *Head of the Department of Agriculture, Muslim University, Aligarh*
- A. R. VYAS, Deputy Principal Information Officer, Ministry of Agriculture**

- H. B. SHAHI, M.Sc., M.R.C.V.S., D.T.V.M.,** *Director of Veterinary Services, Central Provinces and Berar, Nagpur.*
- BIRBAL SAHNI, M.A., Sc.D. (Cantab.), D.Sc., (Lond.), F.R.S.,** *Professor of Botany, Lucknow University*
- HEM SINGH PRUTHI, M.Sc., Ph.D., Sc.D. (Cantab.), F.R.A.S.B., F.N.I.,** *Plant Protection Adviser to the Government of India*
- Z. R. KOTHAVALLA, B.Ag., D.Sc., N.D.D.,** *Dairy Development Adviser to the Government of India*
- G. S. CHEEMA, D.Sc., I.A.S.,** *Fruit Development Adviser to the Government of India*
- BAINI PRASAD, D.Sc., F.R.S.E., F.R.A.S.B., F.Z.S., F.L.S., F.N.I., M.B.O.U.,** *Fisheries Development Adviser to the Government of India*
- S. M. SRIVASTAVA, I.C.S.,** *Secretary, Indian Council of Agricultural Research*
- U. N. CHATTERJEE, D.Phil., D.Sc., F.N.A.Sc.,** *Editor, Indian Council of Agricultural Research*

## Editorial Board

- R. L. SETHI, I.A.S.,** *Agricultural Commissioner with the Government of India*
- J. N. MUKHERJEE, D.Sc., F.N.I., F.R.A.S.B., F.C.S.,** *Director, Indian Agricultural Research Institute, New Delhi*
- BIRBAL SAHNI, M.A., Sc.D. (Cantab.), D.Sc., (London), F.R.S.,** *Professor of Botany, Lucknow University*

- G. S. CHEEMA, D.Sc., I.A.S.,** *Fruit Development Adviser to the Government of India*

- P. V. SUKHATME, Ph.D., D.Sc. (Lond.), F.N.I.,** *Statistical Adviser, Indian Council of Agricultural Research*

*Editor*

**U. N. CHATTERJEE, D.Phil., D.Sc., F.N.A.Sc.**

The Editorial Board, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed

to the Secretary, Indian Council of Agricultural Research, Publication Section, New Delhi

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi

## Instructions to Authors

Articles intended for THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the year of publication title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need

be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about  $7\frac{1}{2}$  in.  $\times$   $9\frac{3}{8}$  in. cut), no text figure, when printed, should exceed  $4\frac{1}{2}$  in.  $\times$  5 in. Figures for plates should be so planned as to fill a crown quarto page, the maximum space available for figures being  $5\frac{1}{2}$  in.  $\times$  8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.